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PRECISION FARMING AND ERGONOMIC APPROACHES IN COTTON AND GROUNDNUT CULTIVATION: ENHANCING EFFICIENCY AND SUSTAINABILITY IN AGRICULTURAL PRACTICES OF ODISHA

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ABSTRACT

Precision farming techniques, coupled with ergonomic approaches, are essential for enhancing the efficiency and sustainability of cotton and groundnut cultivation in Eastern India, particularly in Odisha. The labor-intensive nature of these crops, involving manual operations such as land preparation, sowing, intercultural activities, and harvesting, contributes to significant musculoskeletal complaints among farmers. The introduction of precision farm machinery can refine these processes, ensuring precise application of inputs, reducing the ecological footprint, and minimizing physical strain. Key physiological parameters, including working heart rate (WHR), oxygen consumption rate (OCR), and energy expenditure rate (EER), were measured across for both crops. The findings revealed considerable strain on growers during operations such as ridge and furrow making (WHR: 138 beats min^{-1} for cotton, 142 beats min^{-1} for groundnut) and sowing (WHR: 133 beats min^{-1} for cotton, 136 beats min^{-1} for groundnut). Postural discomfort assessments using RULA and REBA techniques indicated significant discomfort in critical body regions. To address these challenges, the adoption of precision machinery and ergonomic tools, along with proper training, is recommended. These measures will not only boost productivity but also promote a sustainable and healthier working environment for cultivators of both cotton and groundnut.

***Key words*:** Cotton cultivation, Ergonomics, Musculoskeletal Complaints, Postural Discomfort, Precision Farming

Introduction

The integration of precision farming techniques into cotton and groundnut cultivation is essential for optimizing input application and reducing the environmental impact of agriculture. In Odisha's Western Undulating Zone, cotton remains a labour-intensive crop, and groundnut in coastal regions. General practice for sowing of cotton is manual sowing and groundnut behind the bullock drawn plough, which is time consuming and requires more labour with significant manual involvement leading to widespread musculoskeletal disorders (MSDs) (Ramazzini, 1964). Addressing these ergonomic challenges through precision farm machinery can significantly improve the efficiency and sustainability of cotton farming, aligning with the broader goals of climate-resilient agriculture (FAO, 2021).

Work-related musculoskeletal disorders (MSDs) are among the most common occupational disorders worldwide, particularly in labour-intensive sectors like agriculture (NIOSH, 2020). Cotton and groundnut cultivation in Eastern India, especially in Odisha, has long been dependent on manual labour for critical operations such as land preparation, sowing, interculture, and harvesting (Kumar and Singh, 2005). This heavy reliance on manual labour has led to a high prevalence of MSDs among farmers, affecting their productivity and overall well-being.

The rise of precision farming offers a solution to these challenges. By integrating precision farm machinery into cotton cultivation practices, it is possible to refine agricultural techniques, ensure the precise application of inputs, and minimize the ecological footprint (Zhang *et al.*, 2002; FAO, 2019). Moreover, the adoption of ergonomic tools and machinery can significantly reduce the physical strain on workers, leading to improved health outcomes and increased efficiency in farming operations.

Material and Methods

This study was conducted in Kalahandi district, a major cotton-producing area in Odisha and Central Farm, OUAT for groundnut. The research focused on assessing the physiological and ergonomic impacts of various cultivation tasks for both the crops. Physiological parameters such as WHR, OCR, and EER were recorded for tasks including ridge and furrow making, sowing, weeding, and harvesting. Postural discomfort was evaluated using the RULA (McAtamney *et al.* 1993) and REBA techniques (Hignett *et al.*, 2000), which are critical for identifying ergonomic risks associated with repetitive motions and poor body posture during manual operations.

Study Area and Subjects

The research was conducted in Kalahandi district, Odisha, a major cotton-producing area in the state. The study focused on 15 randomly selected agricultural workers from Borbhata village, Bhawanipatna, with ages ranging from 18 to 45 years and a minimum of five years of work experience in cotton cultivation.

Data Collection

Anthropometric data were collected using the Integrated Composite Anthropometer (ICA) developed by IIT Kharagpur (Dewangan *et al.*, 2010). Physiological parameters such as working heart rate (WHR), oxygen consumption rate (OCR), and energy expenditure rate (EER) were measured during key cotton cultivation tasks, including ridge and furrow making, sowing, weeding, and harvesting.

Fig. 1: Rapid Entire Body Assessment during field preparation operation.

Physiological Parameters Assessment:

The physiological demands of various cotton cultivation tasks were measured, focusing on key parameters such as WHR, OCR, and EER (Gite *et al.*, 2009). These parameters provide insight into the cardiovascular and metabolic stresses experienced by cotton cultivators during different phases of cultivation.

Working heart rate (WHR)

Monitoring heart rate to gauge the intensity of physical exertion and potential fatigue during prolonged operation. Heart rate is the primary indicator of circulatory function. The number of heart beats (beats min^{-1}) was measured using a heart rate monitor. Working heart rate can be measured using smart watch directly on the operator. The maximum heart rate was measured using the Equation 1.

$$HR_{max} = 220 - Age \qquad ...1$$

Oxygen consumption rate (OCR)

Volume of oxygen consumption has been measured with the help of $K4B_2$ (K4b2™ portable metabolic system was used to directly measure VO_{2max}).

Energy Expenditure rate (EER)

The heart rate (beats min^{-1}) of different subjects (n=15) were measured using heart rate monitor and energy expenditure rate (EER) was calculated by Equation 2.

$$EER\ (kJ\ min^{-1}) = VO_{2work} \times 20.9 \qquad ...2$$

Where,

VO_{2work} = Volume of oxygen consumption during work ($l\ min^{-1}$) and the values ‘20.9’ is constant

Postural Discomfort Assessment

Postural discomfort was evaluated using two widely recognized techniques: Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA).

RULA

RULA is a survey method developed to evaluate

Table 1: RULA (McAtamney *et al.*, 1993) and REBA (Hignett *et al.*, 2000) action levels.

Action level	REBA score	RULA score	Risk level	Action (Including further assessment)
0	1	1-2	Negligible	Not necessary
1	2-3	3-4	Low	May be necessary
2	4-7	5-6	Medium	Necessary
3	8-10	7	High	Necessary soon
4	11-15		Very High	Necessary now

Table 2: Physiological parameters for Cotton and Groundnut Cultivation across different unit operations.

Operation	WHR (beats/min)		OCR (litres/min)		EER (kcal/min)	
	Cotton	Groundnut	Cotton	Groundnut	Cotton	Groundnut
Land Preparation (Ridge and Furrow Making)	138	142	1.75	1.8	9.2	9.5
Sowing (Bending Posture)	133	136	1.6	1.7	8.5	8.9
Intercultural Operations	128	130	1.5	1.55	7.9	8.2
Harvesting	130	135	1.65	1.68	8.7	8.8

ergonomic risk factors associated with upper extremity musculoskeletal disorders[1]. It assesses biomechanical and postural loading on the neck, trunk, and upper limbs[1].

REBA

REBA, on the other hand, is designed to evaluate the risk of musculoskeletal disorders associated with entire body postures. It considers both upper and lower parts of the musculoskeletal system, providing a comprehensive assessment of ergonomic risks.

These methodologies help identify ergonomic issues related to body posture, forces exerted, and repetitive motions during work. The assessment covered the neck, shoulder, arm, lower back, and buttock regions, pinpointing the most problematic areas for cotton growers. Postural stress on the upper extremities of the body parts was analysed by Rapid Upper Limb Assessment (RULA) (McAtamney *et al.*, 1993). The parts of the body are divided into two groups A and B. Group A includes parts of the body like neck, trunk and legs, and Group B includes body parts like wrist, upper and lower arms. Each body parts in frequent posture during working were evaluated. The evaluation conducted in the present study depends on the force or load and other coupling factors.

Results and Discussion

The physiological assessments revealed substantial cardiovascular and metabolic strain on the workers, with

Fig. 2: Rapid Upper Limb Assessment during field preparation operation.

WHR peaking during ridge and furrow making and sowing. The RULA and REBA analyses indicated high discomfort levels in the neck, shoulder, arm, lower back, and buttocks, underscoring the need for ergonomic interventions. The introduction of precision farm machinery, such as mechanized sowing equipment and improved interculture tools, can alleviate these physical stresses and enhance overall productivity. Additionally, the ecological benefits of precision farming, including reduced input wastage and minimized environmental impact, further justify the adoption of these technologies.

Physiological Characteristics

The physiological assessment revealed varying levels of stress across different tasks in cotton and groundnut cultivation. During land preparation (ridge and furrow making), participants experienced a significant increase in working heart rate (WHR), with cotton cultivation showing an average WHR of 138 beats/min and groundnut at 142 beats/min. This reflects the high cardiovascular demand of the task. Correspondingly, the energy expenditure rate (EER) was recorded at 9.2 kcal/min for cotton and 9.5 kcal/min for groundnut, highlighting the physical intensity involved. Similarly, during sowing in a bending posture, the WHR reached 133 beats/min for cotton and 136 beats/min for groundnut. The EER for this operation was 8.5 kcal/min and 8.9 kcal/min for cotton and groundnut, respectively. Intercultural operations exhibited a lower WHR of 128 beats/min for cotton and 130 beats/min for groundnut, with corresponding EER values of 7.9 kcal/min and 8.2 kcal/

Table 3: RULA and REBA score for cotton and groundnut cultivation through manual tasks.

Unit operation	RULA score		REBA score	
	Cotton	Groundnut	Cotton	Groundnut
Field preparation (Ridge and furrow preparation)	5	5	7	6
Sowing (Manual dibbling)	6	5	7	6
Interculture (hoing)	5	5	6	6
Harvesting (uprooting/plucking)	5	6	5	7

min. Harvesting showed a WHR of 130 beats/min for cotton and 135 beats/min for groundnut, with EER values of 8.7 kcal/min and 8.8 kcal/min, respectively. These results underscore the cardiovascular and metabolic strain across various operations, particularly during manual labour in cotton and groundnut cultivation.

Postural Discomfort

The RULA and REBA assessments indicated significant postural discomfort in critical body regions among cotton growers. The neck, shoulder, arm, lower back, and buttock areas received higher discomfort scores due to poor body posture, repetitive movements, and inadequate tools. The results underscore the need for ergonomic interventions to reduce the physical toll on cotton farmers.

Precision Farming and Ergonomics

Implementing precision farm machinery and ergonomic tools tailored to cotton cultivation tasks can significantly reduce musculoskeletal complaints and improve overall efficiency. Innovations such as mechanized sowing equipment, improved interculture tools, and ergonomic harvesting aids can mitigate the physical strain on cotton growers. Additionally, these precision farming techniques ensure the precise application of inputs, reducing waste and minimizing the ecological footprint.

Conclusion

The transition to precision farming in cotton cultivation, supported by ergonomic tools and machinery, is critical for improving the sustainability and efficiency of agricultural practices in Odisha. By reducing the physical and ecological burden on farmers, these approaches contribute to a more resilient and productive agricultural system. Proper training and demonstrations of precision equipment are necessary to ensure the successful implementation of these advancements in the region.

Cotton cultivation in Eastern India, particularly in Odisha's Western Undulating Zone, presents a scenario where ergonomic interventions are imperative to address musculoskeletal complaints. Physiological assessments have highlighted the strain experienced by cotton growers during different cultivation tasks, while postural discomfort evaluations emphasize the need for targeted interventions to alleviate discomfort and reduce the risk of injuries.

The adoption of precision farming techniques, supported by ergonomic tools and machinery, is critical for improving the sustainability and efficiency of agricultural practices in Odisha. By reducing the physical and ecological burden on farmers, these approaches contribute to a more resilient and productive agricultural system. Proper training and demonstrations on the correct usage of these tools are essential to maximize their benefits.

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