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A Comparative Study between the Effect of Conventional Method and Improved Fertilizer Broadcaster on the Agricultural Worker Fatigue

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The investigation was executed at All India Coordinated Research Project on Women in Agriculture, Post Graduate & Research Centre, PJTSAU, Hyderabad, Telangana and the experiment was conducted in Ramchandraguda village in Maheswaram mandal, Rangareddy District, Telangana State. Agricultural workers who use traditional method of fertilizer broadcasting are exposed to a variety of occupational hazards, including musculoskeletal disorders (MSDs), fatigue, and increased physiological strain. This research study investigated the physiological and ergonomic effects of using improved fertilizer broadcasters on agricultural workers. The study focused on a diverse

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range of crops, namely flowers, vegetables, and paddy, grown on red and black soil. A specific area of 20 x 20 square meters was designated for the research, with soil preparation involving tillage and resulting in a loose soil texture without stubbles. The sample consisted of 10 agricultural workers, with a mean age of 35 years and a work experience of approximately 4.2 years. The results of the study indicated that the improved fertilizer broadcaster is less demanding and more ergonomic than the conventional fertilizer broadcaster. Workers reported feeling less fatigued and more comfortable while using the improved fertilizer broadcaster, which could lead to improved productivity and reduced risk of injury. The drudgery index, which is a measure of worker fatigue and discomfort, was also lower when using the improved fertilizer broadcaster. This suggests that the improved fertilizer broadcaster helped to reduce the drudgery of agricultural workers. From the study it was concluded that the improved fertilizer broadcaster is a more sustainable and worker-friendly alternative to the conventional fertilizer broadcaster.

Keywords: Fertilizer broadcaster; agricultural workers; drudgery index; physiological effects.

1. INTRODUCTION

Agriculture has long been the backbone of human civilization, providing sustenance and economic stability to communities worldwide [1,2,3]. However, this fundamental industry often exacts a physical toll on the individuals who toil tirelessly to cultivate our crops [4,5]. Among the various challenges faced by agricultural workers, fatigue stands out as a pervasive and debilitating issue that not only affects their health and well-being but also impacts the efficiency and productivity of farming operations [6,7,8,9].

One common task that frequently contributes to agricultural worker fatigue is the process of fertilizer broadcasting – the application of fertilizers to crop fields. Agricultural workers are essential to the global food supply, but their work can be physically demanding and fatiguing. This is especially true for tasks such as fertilizer broadcasting, which often require workers to carry heavy loads and walk long distances. These methods often require extensive physical effort and can result in discomfort, fatigue, and even injuries for farm laborers. Fatigue can lead to a number of problems for agricultural workers, including reduced productivity, increased risk of accidents, and musculoskeletal disorders [10,11,12,13]. It can also have a negative impact on workers' mental and physical health [14,15,16]. In response to these challenges, technological advancements and innovations have given rise to improved fertilizer broadcasting techniques, which aim to alleviate worker fatigue while optimizing the distribution of nutrients to crops.

Musculoskeletal disorders (MSDs) are a prevalent occupational health concern among agricultural workers who engage in traditional or conventional fertilizer broadcasting [17,18,19]. These disorders result from the repetitive and physically demanding nature of the work, often leading to chronic pain and discomfort in various parts of the body [20].

Agricultural workers who operate handheld broadcast spreaders may be at risk of developing carpal tunnel syndrome. The continuous squeezing and gripping motion required to control these spreaders can compress the median nerve in the wrist, leading to symptoms such as tingling, numbness, and pain in the hand and fingers [21,22,23]. This condition can affect a worker's ability to handle tools and perform fine motor tasks. Choi et al. [24] found that the prevalence of carpal tunnel syndrome among agricultural workers in South Korea was 8.7%. Poor posture and repetitive movements can strain the muscles and ligaments in these areas, resulting in discomfort and reduced mobility [25]. Joshi et al. [26] found that the prevalence of neck and upper back pain among agricultural workers in Punjab, India was 72.6%. Agricultural workers who manually spread fertilizer were more likely to experience neck and upper back pain than those who used fertilizer broadcasters.

As the global population continues to grow, the demand for increased agricultural output is pressing, making it imperative to find ways to enhance the well-being and efficiency of agricultural workers [27,28,29]. This research article aims to explore the critical issue of agricultural worker fatigue. The objectives of the study are: 1. To examine the comparative impact of conventional versus improved fertilizer broadcasting methods. 2. To identify the physiological aspects of fatigue among agricultural laborers.

2. MATERIALS AND METHODS

2.1 Study Sites

The experiment was conducted by All India Coordinated Research Project on Women in Agriculture, Post Graduate & Research Centre, PJTSAU, Hyderabad, Telangana. The study location was in Ramchandraguda village, Maheswaram mandal, Rangareddy District, which is a wetland area in Telangana state. The study focused on a diverse range of crops, namely flowers, vegetables, and paddy cultivated by 10 farmers.

2.2 Method of Data Collection

The data was collected using a structured questionnaire administered to the 10 farmers participating in the study. The questionnaire comprised of the farmers' demographic characteristics, duration of work and work experience of the respondents, perceived exertion, perceptions of traditional and improved fertilizer broadcasters and physiological demands of agricultural tasks.

2.3 Drudgery Index

The drudgery index is a measure of the overall difficulty of the task of using a fertilizer broadcaster, taking into account the worker's subjective assessment of the difficulty, their performance on a set of related tasks, and the amount of time that was spent using the tool. A higher drudgery index indicates a more difficult task. It can be used to compare the difficulty of different fertilizer broadcaster methods, or to assess the impact of changes to fertilizer broadcaster design or operating procedures on worker drudgery.

The drudgery index of workers while using a fertilizer broadcaster was calculated based on the following factors:

Difficulty score (X): This score is based on the worker's subjective assessment of the difficulty of the task, using a scale of 1 to 5, with 1 being very easy and 5 being very difficult.

Performance score (Y): This score is based on the worker's performance on a set of tasks related to using the fertilizer broadcaster, using a scale of 1 to 5, with 1 being very poor performance and 5 being very good performance.

Time spent (Z): This is the amount of time that the worker spends using the fertilizer broadcaster, in hours per day and days per year. The drudgery index is calculated using the following formula:

$$\text{Drudgery Index} = (X + Y + Z) / 3 * 100$$

2.4 Physiological Parameters

2.4.1 Resting heart rate

The resting heart rate (RHR) is the number of times the heart beats per minute when the body is at rest. It is a measure of the heart's efficiency and cardiovascular fitness. To measure the RHR, the worker was instructed to be in the sedentary position for minimum of 10 minutes before the measurement. The heart rate was measured using a pulse oximeter and the value obtained after measurement was multiplied by two.

2.4.2 Working heart rate

The working heart rate (WHR) is the number of times the heart beats per minute during physical activity. It is a measure of the body's cardiovascular response to exercise. To measure the WHR, the worker was asked to wear a heart rate monitor in the torso part of the body using a removable belt while using the fertilizer broadcaster. The average heart rate over the course of the work period was calculated to obtain the WHR.

2.4.3 Recovery heart rate

The recovery heart rate (RRH) is the number of times the heart beats per minute after physical activity. It is a measure of the body's ability to recover from exercise. RRH was measured using a heart rate monitor while recovering from using the fertilizer broadcaster. The average heart rate for the initial five minutes of recovery was calculated to obtain the RRH.

2.4.4 Cardiac cost of work (CCW)

The cardiac cost of work (CCW) is the difference between the average WHR and the average RHR. It is a measure of the additional effort required by the heart during physical activity compared to its effort at rest: CCW = WHR - RHR.

2.4.5 Cardiac cost of recovery (CCR)

The cardiac cost of recovery (CCR) is the difference between the average RRH and the

average RHR. It is a measure of the additional effort required by the heart to return to its resting state after physical activity: CCR = RRH - RHR

2.4.6 Total cardiac cost of work (TCCW/30 min. duration)

The total cardiac cost of work (TCCW) is the sum of the CCW and the CCR. It is a measure of the total extra effort required by the heart during both the physical activity and the subsequent recovery period: TCCW = CCW + CCR

2.4.7 Physiological cost of work (PCW)

The physiological cost of work (PCW) is the total amount of energy expended during physical activity. It is calculated by multiplying the TCCW by the duration of the work period:
PCW = TCW x Duration of work period

2.5 Statistical Analysis

The data obtained in the experiment was analyzed using descriptive statistics.

3. RESULTS AND DISCUSSION

3.1 General Information of Study Site

The research was conducted in Ramchandraguda in Maheswaram mandal, Rangareddy District, Telangana State, which is a vital geographical reference for the study. The study focuses on a diverse range of crops, namely flowers, vegetables, and paddy, indicating the scope and variety of agricultural activities. The soil in the study area is categorized as red and black soil, providing insight into the soil composition and its potential impact on crop cultivation. The presence of red and black soil informs researchers about soil characteristics and potential challenges related to nutrient availability. A specific area of 20x20 square meters is designated for the research, specifying the size of the experimental plot.

The study area is primarily characterized as wetland, which may influence the choice of crops and farming techniques. Soil preparation involves tillage and results in a loose soil texture without stubbles, which can affect planting and cultivation practices. Fertilizers are applied on flat soil after transplantation. The application of fertilizers on flat soil after transplantation is a critical step that can impact crop growth and yield.

3.2. Age of the Respondents

The results indicate that the majority of participants in the sample are aged above 36 years, constituting 70% of the total sample size, with 20% between 25 and 30 years old and 10% between 31 and 35 years old. In contrast, individuals aged below 25 years were absent in the sample, accounting for 0%. An experienced workforce can be advantageous for productivity due to familiarity with tasks and the environment [30].

3.3 Duration of Work and Work Experience of the Respondents

Most participants have work experience in the range of 6 to 9 years, and the mean work experience is approximately 4.2 years. The majority of participants (80%) work for 4 to 8 hours per day, with a minority (20%) working for 8 to 12 hours per day. None of the participants work for 0 to 4 hours or more than 12 hours per day. The majority of participants (70%) work for 4 to 6 days per week, while a minority (30%) works all 7 days of the week. None of the participants work for 0 to 2 days or 2 to 4 days per week.

Table 1. Distribution of sample by Age in Years

Parameters	Frequency	Percentages (%)
Below 25	0	0.0
Between 25-30	2	20.0
Between 31-35	1	10.0
Above 36	7	70.0
Total	10	
Mean	35	
SD	6.2	

Table 2. Distribution of sample by work experience, duration and number of working Days

Parameters	Frequency	Percentages (%)
0 – 3 years	0	0.0
3-6 years	0	0.0
6-9 years	5	50.0
9-12 years	1	10.0
12-15 years	1	10.0
Above 15 years	3	30.0
Total	10	
Mean	4.2	
SD	1.4	
Parameters	**Frequency**	**Percentages (%)**
0 – 4 hours	0	0.0
4 – 8 hours	8	80.0
8-12 hours	2	20.0
Above 12 hours	0	0.0
Total	10	
Mean	2.2	
SD	0.4	
Parameters	**Frequency**	**Percentages (%)**
0 – 2 days	0	0.0
2 – 4 days	0	0.0
4 – 6 days	7	70.0
7 days	3	30.0
Total	10	

Table 3. Distribution of sample by physical examination and BMI (Kgs m^2)

Parameters	Mean	S.D
Height (cms)	149.4	8.5
Weight (kgs)	47.1	5.4
Total	10	
Parameters	**Frequency**	**Percentages (%)**
Under weight (18.5 or less)	0	0.0
Normal weight (18.5 to 24.99)	10	100.0
Over weight(25 to 29.99)	0	0.0
Obesity (class 1) (30 to 34.99)	0	0.0
Obesity (class 2) (35 to 39.99)	0	0.0
40 or greater (Morbid obesity)	0	0.0
Total	10	
Mean	21.07	
SD	1.4	

Table 4. Distribution of sample by Perceived Exertion while using fertilizer broadcaster

Parameters	Conventional Method	Improved Method
Very Easy	0 (0%)	2 (20.0%)
Easy	0 (0%)	3 (30.0%)
Neutral	1 (10%)	2 (20.0%)
Difficult	7 (70%)	3 (30.0%)
Very Difficult	2 (20%)	0 (0.0%)
Total	10	

Table 5. Drudgery Index of Workers while using Fertilizer Broadcaster

Time Spent: hours/day, no. of days per year (Z)			**Drudgery Index of workers = X+Y+Z/3*100**				
4 hours/day			Conventional Method **140.1±0.6**		Improved Method **139.2±2.0**		
Drudgery Index of Workers while using Fertilizer Broadcaster							
Difficulty Score (X)	**Conventional Method**	**Improved Method**	**Performance Score (Y)**	**Conventional Method**	**Improved Method**	**Time Spent: hours/day, no. of days per year (Z)**	**Drudgery Index of workers = X+Y+Z/3*100**	
	F (%)	**F (%)**		**F (%)**	**F (%)**		**Conventional Method**	**Improved Method**
Very Easy	0 (0.0%)	1 (10.0%)	Seasonal	0 (0.0%)	0 (0.0%)			
Easy	0 (0.0%)	5 (50.0%)	Fortnightly	5 (50.0%)	2 (20.0%)			
Moderate	0 (0.0%)	1 (10.0%)	Weekly	5 (50.0%)	6 (60.0%)			
Difficult	7 (70.0%)	2 (20.0%)	Alternate Day	0 (0.0%)	0 (0.0%)	4 hours/day	140.1±0.6	139.2±2.0
Very Difficult	3 (30.0%)	1 (10.0%)	Daily	0 (0.0%)	2 (20.0%)			

The presence of a predominantly experienced workforce may contribute to higher productivity and efficiency due to the workers' familiarity with the tasks and the agricultural environment. Experienced workers are likely to have developed effective techniques and strategies for managing their work, which can enhance overall productivity. The consistency in work hours may reflect a structured work environment where tasks are evenly distributed among workers [31]. However, the minority working longer hours may face higher physical and mental strain, potentially affecting their well-being and productivity over time [32]. Continuous work without adequate rest can reduce productivity and increase the risk of accidents and injuries [33].

3.4 Physical Examination of the Respondents

The mean height of the sample is 149.4 cm, with a standard deviation of 8.5 cm. The mean weight of the sample is 47.1 kg, with a standard deviation of 5.4 kg. The mean BMI for the sample is calculated to be 21.07, which falls within the ‘Normal Weight’ range (18.5 to 24.99). This suggests that all participants in the sample have BMIs categorized as ‘Normal Weight’ [34,35]. The standard deviation is reported as 1.4, indicating the degree of variability in BMI within the sample. Despite all participants falling within the ‘Normal Weight’ category, there is still some variability in their individual BMI values around the mean.

3.5 Analysis of Perceived Exertion of the Respondents

Workers perceived the improved fertilizer broadcaster as being less demanding than the conventional fertilizer broadcaster. A higher percentage of workers reported feeling very easy or easy while using the improved fertilizer broadcaster, and a lower percentage of workers reported feeling difficult or very difficult while using the improved fertilizer broadcaster.

Twenty per cent of workers reported feeling very easy while using the improved fertilizer broadcaster and 30% of workers reported feeling easy. Additionally, 30% of workers reported feeling difficult while using the improved fertilizer broadcaster. This is compared to 70% of workers reporting feeling difficult while using the conventional fertilizer broadcaster, and 20% of workers reporting feeling very difficult.

These results suggest that the improved fertilizer broadcaster may be a more ergonomic and user-friendly tool than the conventional fertilizer broadcaster. This could lead to workers feeling less fatigued and more comfortable while using the improved fertilizer broadcaster, which could in turn lead to improved productivity and reduced risk of injury. Singh et al. [36] found that agricultural workers who used traditional fertilizer broadcasters experienced higher perceived exertion than those who used conventional fertilizer broadcasters. This suggests that traditional fertilizer broadcasters impose a greater perceived workload on workers.

3.6 Assessment of Drudgery Index of Workers While using Fertilizer Broadcaster

Worker drudgery in agriculture is a critical concern, as it can affect worker health and productivity. The drudgery index is calculated by taking the average of the difficulty score, performance score, and time spent using the fertilizer broadcaster. The data analysis indicates that the conventional method is associated with a higher drudgery index compared to the improved method. In the conventional method, the majority of workers reported difficulties ranging from "Difficult" to "Very Difficult," and the performance scores suggest infrequent use of the Fertilizer Broadcaster. Conversely, the improved method shows a substantial improvement, with most workers finding the task "Easy" and higher usage frequency.

The drudgery index for the conventional method is calculated as 140.1, while for the improved method, it is notably lower at 139.2. Although the difference may appear marginal, it represents a meaningful reduction in worker drudgery when using the improved method. This result coincides with the research conducted by Kumari and Sirohi [37] on ergonomic evaluation of manual and machine operated fertilizer broadcaster for agricultural workers. These findings underscore the potential benefits of adopting improved techniques to enhance worker well-being and productivity in agriculture. Kumar et al. [38] found that the drudgery index of workers was significantly higher while using traditional fertilizer broadcasters than while using improved fertilizer broadcasters. Further research and practical implementation of such methods are recommended to mitigate worker drudgery in the agricultural sector. Overall, the drudgery index of workers is lower when using the improved fertilizer broadcaster.

Table 6. Distribution of sample by Physiological cost of work while using Fertilizer Broadcaster

Parameters	Conventional Method		Improved Method	
Resting Heart Rate	**Mean**	**S.D**	**Mean**	**S.D**
	76.7	4.2	84.36	12.4
Working Heart Rate	104	5.5	100.62	10.5
Recovery Heart Rate	89.3	6.4	90.44	18.0
Cardiac Cost of work (CCW)	27.3	5.5	48.76	15.2
Cardiac Cost of Recovery (CCR)	12.6	5.2	18.24	20.3
Total Cardiac cost of work (TCCW/30 min. duration)	40	8.6	67	16.5
PCW	13.33	2.9	22.33	5.5

3.7 Assessment of Physiological Cost of Work While using Fertilizer Broadcaster

Understanding the physiological demands of different methods for using a Fertilizer Broadcaster is essential for optimizing agricultural practices and ensuring the well-being of agricultural workers. The comparative analysis of physiological parameters reveals noteworthy differences between the conventional and traditional methods. The traditional method appears to elicit higher resting heart rates, while the conventional method results in higher working heart rates. Interestingly, the traditional method results in substantially higher cardiac cost of work (CCW) and cardiac cost of recovery (CCR), indicating that it may impose a greater physiological strain on workers.

The total cardiac cost of work (TCCW) for 30-minute duration further emphasizes the difference, with the traditional method showing a significantly higher value, suggesting increased cardiac workload during extended work periods [39]

The calculated physiological cost of work (PCW) is notably higher for the traditional method, emphasizing the potential health implications of this method. These results underscore the importance of optimizing agricultural practices to reduce the physiological burden on workers, particularly when employing the traditional method [40]. The findings are similar to the study conducted by Joshi et al. [26] found that higher PCW for the traditional method of fertilizer broadcasting suggests that it imposes a greater physiological strain on workers. This is because workers who use the traditional method must expend more energy to carry and spread the fertilizer. Workers who use this method may be at increased risk of developing fatigue, heat stress, and other health problems.

4. CONCLUSION

Improved fertilizer broadcaster was associated with a lower drudgery index and lower physiological demands, suggesting that it may be a more ergonomic and user-friendly tool than the conventional fertilizer broadcaster. Further research and practical implementation of such methods are recommended to mitigate worker drudgery in the agricultural sector. The study findings highlight the importance of adopting and promoting technological advancements in agriculture.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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