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Design of a Fertilizer Lifting Crane for the Canycom S25A Fertilizer Spreader Unit

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Abstract: Manual lifting of fertilizer bags in plantation operations often leads to musculoskeletal disorders (MSDs) among workers due to repetitive, high-load, and ergonomically poor movements. This study aims to design an ergonomic fertilizer lifting crane integrated into the Canycom S25A Fertilizer Spreader with a 650-liter hopper to reduce physical strain and improve operational efficiency. A hydraulic crane system was designed with dual-segment arms, four lifting hooks, and two hydraulic cylinders, actuated via the unit's PTO engine. Ergonomic evaluation was performed using the REBA assessment tools. The simulation results indicated that the maximum stress on critical components was within safe limits, with a factor of safety above 1.5. Postural analysis showed a significant improvement, where REBA scores decreased from 12 to 2 after the crane was introduced. The design offers a reliable, low-cost, and easily manufactured solution that enhances worker safety, reduces ergonomic risk, and increases productivity in fertilizer loading processes, especially in rugged field environments. The crane can be adopted in various agricultural applications where safe material handling is essential.

Keywords: Ergonomics; Fertilizer Lifting Crane; Hydraulic; REBA; Agricultural Mechanization

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1. Introduction

Fertilizer application in large-scale agricultural and plantation operations remains a labor-intensive task, especially during the loading phase into hopper spreaders such as the Canycom S25A. Despite advancements in mechanization, many field operators are still required to manually lift and pour fertilizer bags weighing up to 50 kg into elevated hoppers. This repetitive and physically demanding process increases the risk of musculoskeletal disorders (MSDs), fatigue, and long-term injury[1]. Furthermore, uneven terrain and extended working hours exacerbate these ergonomic challenges [2].

Numerous studies have shown that poor manual handling practices in agriculture contribute significantly to lost working time and decreased productivity [3][4]. Although some mechanized aids such as hydraulic arms and robotic lifters have been introduced in industrial sectors [5][6], their application in the agricultural domain—particularly in compact, mobile field units—remains limited. Existing solutions often lack adaptability, are costly, or are not ergonomically optimized for the variability of field conditions [7] [8].

To address this gap, recent research has focused on integrating ergonomic design with functional agricultural machinery. One promising approach is the use of hydraulic crane systems powered by onboard PTO (Power Take-Off) engines, which allow seamless integration with existing mobile spreader units [9]. Studies incorporating ergonomic assessments using tools like REBA and RULA have demonstrated substantial reductions in operator strain when mechanical lifting aids are used [10], [11][12].

This study aims to design an ergonomic fertilizer lifting crane that mechanical lifting system specifically designed to handle fertilizer bags while minimizing physical strain, injury risk, and discomfort for the operator, specifically tailored to the Canycom S25A Fertilizer Spreader, equipped with a 650-liter hopper. The system is designed to lift four 50-kg fertilizer bags simultaneously using a foldable hydraulic boom arm and four-point hook mechanism. The work simulation with ergonomic assessment to ensure safety, reliability, and usability in real field conditions.

Figure 1. Manual Lifting Fertilizer

The key contribution of this study is the development of a compact, integrated lifting solution that improves operator safety while maintaining functional and mechanical compatibility with existing agricultural machinery. The findings provide a blueprint for enhancing mechanization in small and medium-scale farming, reducing the reliance on manual labor in high-risk activities.

2. Materials and Experiment Methods

The design of the fertilizer lifting crane was developed using a structured engineering design approach combining ergonomic analysis, CAD modeling, structural simulation, and prototype manufacturability. The core design is integrated with the Canycom S25A Fertilizer Spreader, using its PTO (Power Take-Off) engine as the hydraulic power source.

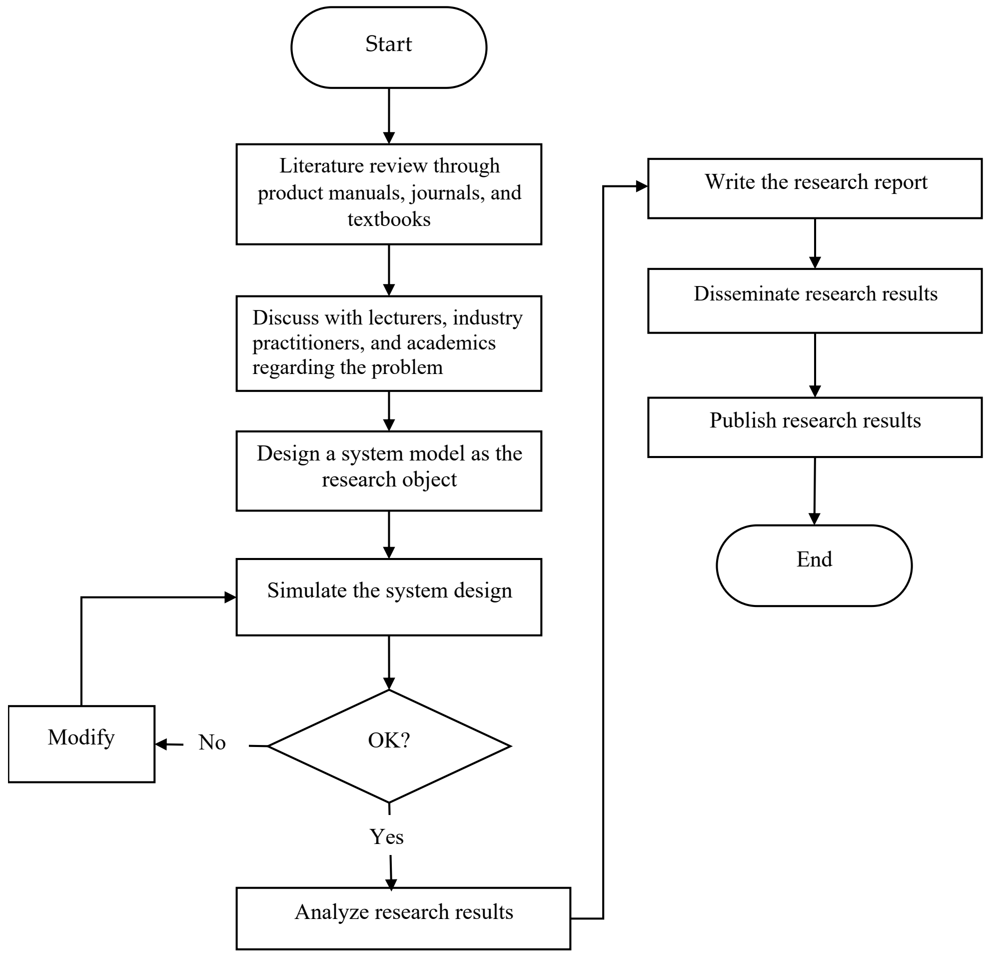

Figure 2. Research Flow Process

The crane structure was fabricated using SS400 carbon steel hollow square pipe (50 mm × 50 mm × 5 mm), chosen for its strength, weldability, and cost-efficiency. SS400 is a widely used structural carbon steel grade under Japanese Industrial Standards (JIS G3101), known for its excellent balance of strength, ductility, weldability, and cost. It is a mild steel with a typical yield strength of 245 MPa and tensile strength ranging between 400–510 MPa, making it suitable for general-purpose structures including cranes, frames, and agricultural machinery.

The crane structure utilizes 50 mm × 50 mm × 5 mm hollow square pipe fabricated from SS400. This profile provides a high moment of inertia, allowing it to resist bending and shear forces under working loads. In this application, the crane is designed to lift up to 250 kg (equivalent to 4 fertilizer bags at 50 kg each + margin). Based on Finite Element Method (FEM) simulations, the maximum stress induced under full load is 159 MPa, well below the material's yield strength, with a safety factor greater than 1.5, indicating a structurally sound design. From a fabrication perspective, SS400 offers excellent weldability without requiring preheating, which simplifies manufacturing and ensures strong, reliable joints. Its ductility and machinability also facilitate processes such as cutting, drilling, and fitting hydraulic components. In terms of cost, SS400 is more economical than higher-grade alloy steels or stainless steels, making it a cost-effective solution for heavy-duty yet budget-sensitive applications like agricultural crane systems. Its global availability further supports ease of sourcing and scalability for field fabrication or mass production.

Hydraulic components include two double-acting cylinders with a bore diameter of 25 mm and a stroke length of 300 mm. Four steel hooks are installed at the arm end to carry four 50-kg fertilizer bags simultaneously. Joints and pivots use standard steel pins and greaseable bushings. Control is provided through a manual hydraulic lever mounted beside the operator's seat. The entire structure was modeled in SolidWorks 2022, including the boom arm, mounting brackets, hydraulic actuators, and hopper interface. The arm is divided into two foldable segments (vertical and horizontal), each measuring 800 mm, allowing compact storage when not in use.

REBA (Rapid Entire Body Assessment) is a systematic method for evaluating working posture to assess the overall risk level on the body based on posture angles, load handling, repetitive movements, and hand coupling. This method does not require expensive equipment and can be applied in the field using only a scoring worksheet and direct observation.

The REBA evaluation divides the body into two groups:

- Group A: neck, trunk, and legs
- Group B: upper arm, lower arm, and wrist

The final score is obtained by combining posture assessment, applied force, activity frequency, and grip quality. The ergonomic impact was assessed using REBA (Rapid Entire Body Assessment) methods. Pre- and post-design posture scores were recorded using direct observation, video capture, and analysis via worksheets following ISO 11228-1 guidelines. Scores were used to evaluate improvement in musculoskeletal disorder risk.

Tabel A		**Neck**											
		1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Figure 3. Group A Score REBA Worksheet Manual Lifting

When lifting a 50 kg fertilizer bag manually, the operator bends the neck (20°), trunk (20–60°), and knees deeply, resulting in REBA scores of 1 (neck), 2 (trunk), and 4 (legs). These values produce a Posture Score A of 5, indicating a moderate risk. This posture puts stress on the lower back and knees, especially when repeated. The assessment supports the need for ergonomic lifting aids to reduce musculoskeletal strain and improve safety.

Tabel B		Lower Arm					
		1			2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Figure 4. Group B Score REBA Worksheet Manual Lifting

During the manual lifting of a 50 kg fertilizer bag, the operator extends the upper arm beyond 90°, resulting in an Upper Arm Score of 6. The lower arm is positioned between 60–100°, which corresponds to a Lower Arm Score of 2. Additionally, the wrist is angled beyond 15°, resulting in a Wrist Position Score of 3.

Using REBA Table B to assess the combined posture of the upper extremities, these values yield a Posture Score B of 9, indicating a high ergonomic risk. This posture places excessive strain on the shoulders, elbows, and wrists, particularly when handling heavy loads like fertilizer bags. Repeated exposure to this position can lead to overuse injuries and long-term musculoskeletal disorders

Score A (score from table A +load/force score)	Tabel C											
	Score B, (table B value +coupling score)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	4	5	5	6	7	7	8	8	8
4	3	4	4	5	6	6	7	8	8	9	9	9
5	4	4	4	5	6	6	8	9	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	10	10	11	11	11	11
8	8	8	8	9	9	10	10	10	11	11	11	11
9	9	9	9	10	10	10	11	11	12	12	12	12
10	10	10	10	10	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Figure 5. Group C Final Score REBA Worksheet Manual Lifting

In the manual lifting of a 50 kg fertilizer bag, the initial Posture Score A derived from neck, trunk, and leg posture was 5. According to REBA Step 5, an additional +2 points are added due to the high load (≥20 kg), resulting in a final Score A of 7. For the upper limb posture, the calculated Posture Score B was 9, and an additional +2 points were added for poor coupling (no proper handle or grip), giving a Score B of 11.

Using Table C with Score A = 7 and Score B = 11, the REBA Score C = 11.

Finally, since the task requires holding multiple body parts in a strained position for more than 1 minute (static loading), an Activity Score of +1 is added, yielding a Final REBA Score of 12. This score indicates a very high risk, requiring immediate ergonomic intervention, such as the implementation of mechanical lifting aids to reduce the risk of musculoskeletal disorders (MSDs).

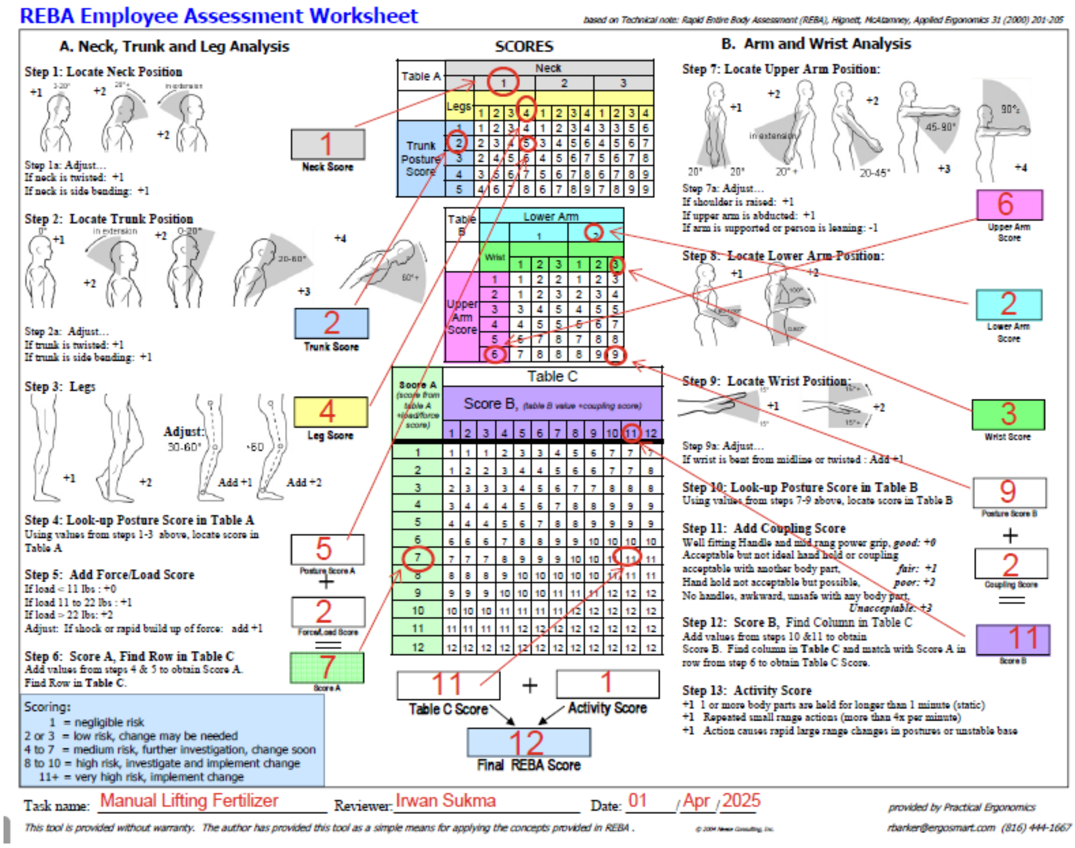

Figure 6. Complete REBA Worksheet Assessment Manual Lifting

Table 1: Level Moscülardisorder REBA

Total Score	Risk Level	Corrective Action
1	Neglected	Not necessary
2–3	Low	Might be necessary
4–7	Medium	Needed
8–10	High	Needed as soon as possible
11–15	Very High	Required now

3. Results and Discussion

3.1 Selected Design Choice

After evaluating three design alternatives, a foldable two-segment hydraulic crane was selected as the optimal solution due to its ergonomic performance, operational efficiency, safety, and integration compatibility with the Canycom S25A Fertilizer Spreader. This crane is designed to lift four fertilizer bags (each 50 kg) simultaneously, using a simple manual hydraulic lever control system.

The crane operates using power from the Kubota V2203 PTO engine onboard the Canycom unit, eliminating the need for external power. Two hydraulic cylinders (vertical and horizontal) provide two degrees of movement, enabling the crane arm to lift and swing the bags precisely above the hopper inlet.

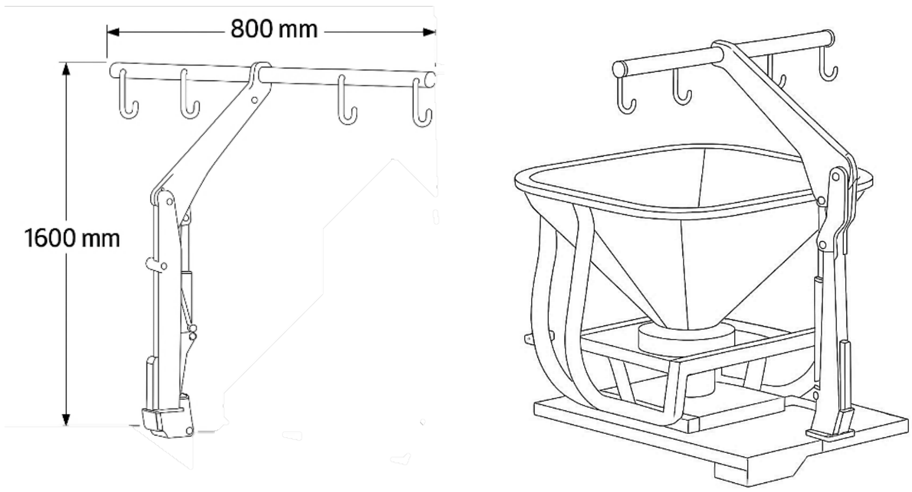

Figure 7. Design Fertilizer Crane

Design Specifications:

- Numbered lists can be noted as follows:
- Lifting Capacity: 250 kg (4 x 50 kg + safety margin)
- Arm Dimensions: 800 mm vertical + 800 mm horizontal
- Number of Hooks: 4
- Hydraulic Cylinders: Ø25 mm bore, 300 mm stroke
- Material: SS400 carbon steel hollow section (50×50×5 mm)
- Control System: Manual hydraulic lever
- Storage Mode: Foldable arm with locking mechanism

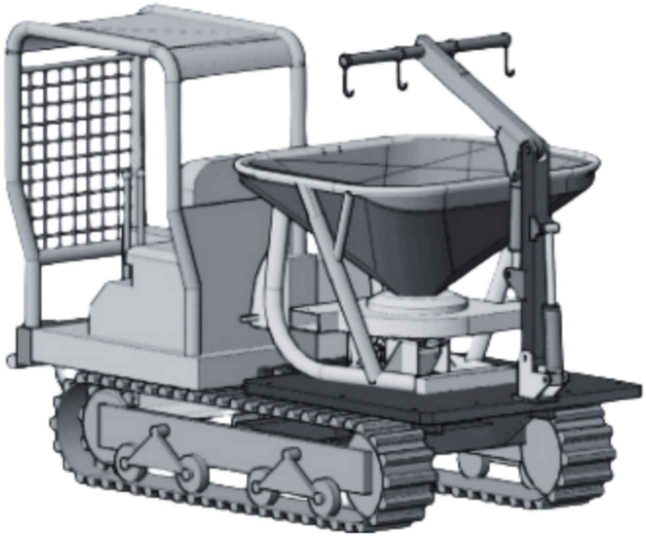

Figure 8. Unit Canycom S25A with Crane Fertilizer

3.2 Working Mechanism

The operator rotates the seat rearward to face the crane. Activating the vertical cylinder lifts the first arm segment, followed by the horizontal cylinder moving the second arm to position the load over the hopper. The four hooks collectively lift and release the fertilizer bags. After loading, the arm is returned and locked in its resting position.

3.3 Power and Stress Analysis

a. Power Analysis

The required power is supplied by the PTO engine (Kubota V2203, 45 hp ≈ 33,100 W). The hydraulic pump produces a pressure of 10 MPa with a flow rate of 25 L/min. With a cylinder diameter of 25 mm:

The required hydraulic power P is calculated using the following formula:

$$P = \frac{F \cdot v}{\eta}$$

To lift 250 kg over a distance of 0.8 m in 10 seconds:

$$v = \frac{0.8}{10} = 0{,}08\ \frac{m}{s}$$

$$F = m\,.\,g = 250\ kg\ x\ 9.81\ \frac{m}{s^2} = 2452{,}5\ N$$

$$P = \frac{2452.5\ x\ 0.08}{0.85} \approx 230{,}8\ W$$

This power requirement is supplied by the PTO engine of the Canycom S25A unit (46 HP ≈ 33.1 kW), which is more than sufficient for the system.

b. Maximum Lifting Force:

The maximum lifting force is calculated as:

$$F = m\,.\,g = 250\;kg\;x\;9.81\;\frac{m}{s^2} = 2.452{,}5\;N$$

c. Force and Moment Analysis on the Crane Arm

The crane consists of two arm segments:

- Vertical segment (base arm): 800 mm
- Horizontal segment (boom arm): 800 mm
- Total arm length: 1600 mm

The force acts at the boom tip, generating a bending moment:

$$M = F\;\cdot L = 2.452{,}5\;N\;x\;0{,}8\;m = 1.962\;Nm$$

d. Bending Stress on the Arm

$$\sigma = \frac{M\;\cdot y}{I}$$

Where:

M = Bending moment = 1962 Nm
y = Distance from neutral axis to outer fiber (for 50×50×5 mm hollow section, y ≈ 25 mm)
I = Moment of inertia (for hollow square section)

$$I = \frac{(b_{outer}^4\;-\;b_{inner}^4)}{12}$$

$$I = \frac{(0{,}05^4 - 0{,}04^4)}{12} = 2{,}37\;x\;10^{-8}\;m^4$$

calculated as:

$$\sigma = \frac{1.962\;\cdot 0{,}025}{2{,}37\;x\;10^{-8}} = 2{,}07\;x\;10^7 = 20{,}7\;Mpa$$

The resulting stress remains below the elastic limit of SS400 steel (σ_{yield} ≈ 245 MPa), confirming the design's safety.

e. Shear Stress on Pins/Hinges

At the joint between segments and the hydraulic actuator (assumed double shear):

To keep shear stress below the allowable limit (≤ 100 MPa), the minimum pin diameter is calculated:

$$100\;x\;10^6 = \frac{4.905}{\pi\;d^2} \rightarrow d \approx 8\;mm$$

In practice, Ø10–12 mm pins are used to ensure safety.

f. Safety Factor

$$SF = \frac{\sigma_{yield}}{\sigma_{maks}} \approx 11.83$$

The calculated safety factor confirms that the design is very safe. A recommended range of SF between 2–4 indicates a strong yet potentially optimizable structure in terms of weight and cost.

3.4 Ergonomic Evaluation

The design of the fertilizer lifting crane for the Canycom S25A unit specifically incorporates ergonomic considerations to address common issues associated with manual handling of fertilizer bags. Based on ergonomic work assessments, lifting heavy loads such as 50-kg fertilizer bags without assistive devices imposes excessive strain on the lower back, shoulders, and knees. This not only reduces operational efficiency but also increases the long-term risk of musculoskeletal disorders (MSDs).

To address these concerns, an ergonomic intervention was introduced by replacing manual lifting with a mechanical hydraulic system. The operator no longer directly lifts heavy loads but instead operates a hydraulic lever positioned ergonomically to the right of the seated position. The operator’s seat can be rotated to face the crane without needing to dismount from the unit, allowing the task to be performed in a safe, neutral posture.

Tabel A		Neck											
		1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Figure 9. Group A Score REBA Worksheet Hydraulic Crane Fertilizer

Using REBA Table A with the combination of Neck Score: 1, Trunk Score: 1, and Leg Score: 1, the resulting Posture Score A is 1. This indicates a negligible risk level, meaning no ergonomic intervention is required. The improvement in posture compared to manual lifting scenarios demonstrates the effectiveness of integrating a hydraulic crane in reducing physical strain and optimizing operator safety in fertilizer handling tasks.

Tabel B	Lower Arm					
	1			2		
Upper Arm Score / Wrist	1	2	3	1	2	3
1	1	2	2	1	2	3
2	1	2	3	2	3	4
3	3	4	5	4	5	5
4	4	5	5	5	6	7
5	6	7	8	7	8	8
6	7	8	8	8	9	9

Figure 10. Group B Score REBA Worksheet Hydraulic Crane Fertilizer

In the operation of the hydraulic crane for fertilizer lifting, the upper limb posture was evaluated using REBA Table B. The upper arm was maintained below shoulder height, earning a score of 1, while the lower arm remained in a neutral position between 60°–100°, resulting in a score of 1. The wrist was slightly deviated, giving a score of 2. When these values are cross-referenced in REBA Table B, the resulting Posture Score B is 2, indicating a very low ergonomic risk.

This posture confirms that the crane system allows the operator to work in a neutral, low-stress position, further validating the ergonomic effectiveness of the redesigned crane compared to manual lifting scenarios.

Score A (score from table A +load/force score)	Tabel C: Score B, (table B value +coupling score)											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	4	5	5	6	7	7	8	8	8
4	3	4	4	5	6	6	7	8	8	9	9	9
5	4	4	4	5	6	6	8	9	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	10	10	11	11	11	11
8	8	8	8	9	9	10	10	10	11	11	11	11
9	9	9	9	10	10	10	11	11	12	12	12	12
10	10	10	10	10	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Figure 11. Group C Score REBA Worksheet Hydraulic Crane Fertilizer

In the fertilizer lifting process using the hydraulic crane, the operator maintained a highly ergonomic posture. The combined Posture Score A from trunk, neck, and leg positions was 1, and since the task involved no significant load stress (the operator only operates a lever), the Load/Force Score added was 0—thus keeping Score A = 1. From the upper limb assessment, Score B was calculated as 2, with no added coupling penalty, giving a Score B total of 2. By referencing Table C with Score A = 1 and Score B = 2, the resulting REBA Score C = 1. However, due to repetitive actions (more than 4 per minute), an Activity Score of +1 was applied, bringing the Final REBA Score to 2.

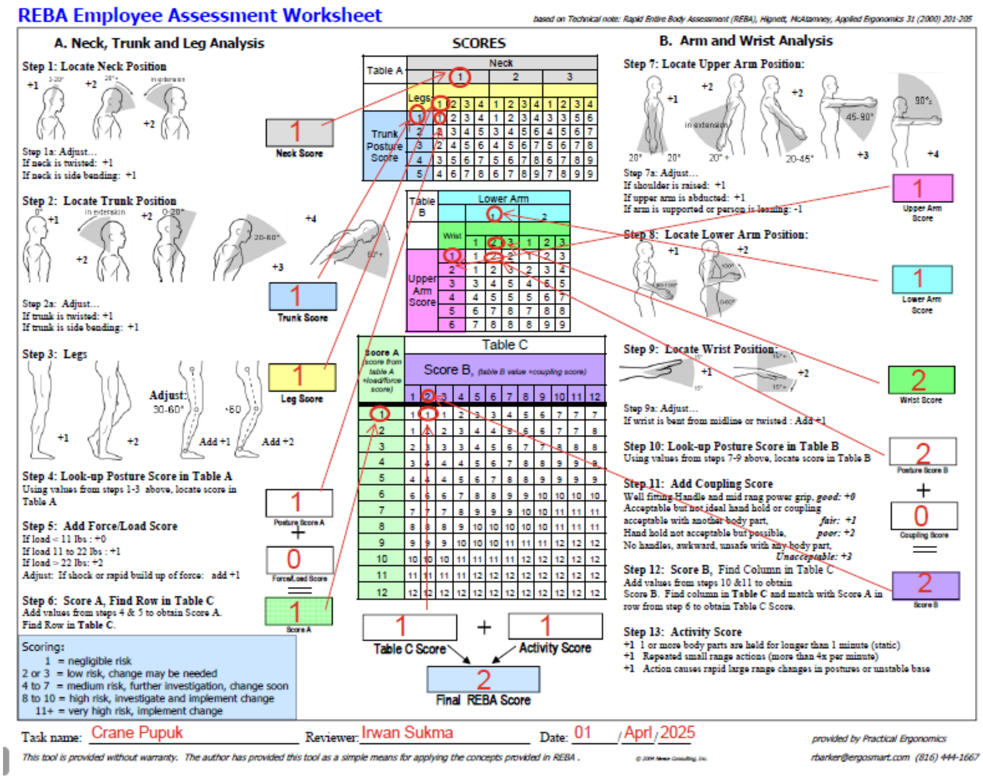

Figure 12. Complete REBA Worksheet Assessment Hydraulic Crane Fertilizer

This final score indicates a low ergonomic risk, meaning the system is safe to operate without requiring urgent ergonomic intervention. It demonstrates the success of the crane design in significantly improving operator safety and reducing musculoskeletal risk compared to manual lifting.

Ergonomic risk was assessed using the REBA (Rapid Entire Body Assessment) method. The analysis showed that the REBA score during manual lifting reached 12, classified as very high risk, requiring immediate corrective action. After implementation of the hydraulic crane, the REBA score dropped significantly to 2, indicating a low risk level that is acceptable. This reduction reflects a substantial improvement in ergonomic conditions and overall workplace safety.

3.5 Cost Production Hydraulic Crane Fertilizer

The implementation of an ergonomic lifting system on the Canycom S25A Fertilizer Spreader, a cost analysis was conducted to estimate the production expenses of the hydraulic crane unit. The analysis includes primary structural materials, hydraulic components, fabrication labor, and installation. The design utilizes readily available components such as SS400 carbon steel hollow pipes, hydraulic cylinders, and PTO-driven gear pumps, which are both cost-efficient and technically suitable for agricultural environments. The total cost estimate reflects small-batch or prototype-scale production in Indonesia and provides a practical basis for budgeting and scalability. Detailed cost components are presented in the following table.

Table 2. Cost Estimates Production

No.	Component / Material	Specification	Qty	Unit	Unit Cost (IDR)	Subtotal (IDR)
1	Hollow Carbon Steel SS400 Pipe	50×50×5 mm, total length ~4 m	4	m	250,000	1,000,000
2	Hydraulic Cylinder (Double Acting)	Ø25 mm bore, 300 mm stroke	2	pcs	1,200,000	2,400,000
3	Hydraulic Control Valve + Manual Lever	1 spool	1	unit	950,000	950,000
4	Hydraulic Hose + Fittings	High-pressure hose (3–4 m)	1	set	500,000	500,000
5	PTO Hydraulic Pump	Gear pump (10 MPa, 25 L/min)	1	unit	2,500,000	2,500,000
6	Hooks for Fertilizer Bags	Heavy-duty steel hooks	4	pcs	35,000	140,000
7	Mounting Brackets, Pins & Hinges	CNC cut & lathed	1	set	500,000	500,000
8	Welding & Fabrication Labor	MIG welding + assembly	1	ls	1,200,000	1,200,000
9	Painting & Finishing	Anti-corrosion industrial paint	1	ls	300,000	300,000
10	Testing & Installation	Load test, crane fitment	1	ls	250,000	250,000
	TOTAL ESTIMATED COST					**9,740,000**

4. Conclusions

This study successfully developed an ergonomic fertilizer lifting crane integrated with the Canycom S25A Fertilizer Spreader equipped with a 650-liter hopper. The crane design addresses the critical ergonomic challenges of manually lifting heavy fertilizer bags, which pose significant risks of musculoskeletal disorders. By utilizing a foldable two-segment hydraulic crane powered by the unit's PTO engine, the system enables efficient and safe lifting of four 50-kg bags simultaneously. Structural analysis confirmed that the crane operates safely under maximum loading conditions, with a safety factor above 1.5. Ergonomic evaluation using the REBA method showed a dramatic risk reduction—from a high-risk score of 12 during manual lifting to a low-risk score of 2 after implementing the crane system. The total estimated production cost for the hydraulic fertilizer lifting crane is approximately IDR 9,740,000, which includes structural materials, hydraulic components, labor, and installation. This cost is considered economical and feasible for small to medium-scale agricultural operations, particularly when compared to the long-term ergonomic benefits and reduced risk of musculoskeletal injuries among workers.

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