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A Study on Quality Control of NFT Hydrophonic Pakcoy (*Brassica rapa chinensis*) in XYZ Farm, Bogor Regency

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ABSTRACT

Besides being known for its efficiency, simplicity, and productivity, the NFT Hydroponic technique is popularly chosen for its high effectiveness in producing high-quality hydroponic vegetables with excellent plant health. This research aims to study the quality control of Hydroponic Pakcoy produced using the NFT Technique at XYZ Hydroponic Farm, Bogor Regency, through (1) identification of types and levels of damage, (2) analysis of factors causing damage; (3) proposing alternative improvements that can be made. Analysis was conducted using statistical quality control (SQC). The results showed the level of damage to hydroponic Pakcoy at XYZ hydroponic farm, which showed uncontrolled damage consisting of damaged leaves, damaged stems, and abnormal shapes or sizes. Fishbone analysis reveals the causes of damage, including lack of knowledge and negligence of labor, how to harvest, and greenhouse damage. Based on the causes of damage, recommendations for improvement that can be made are to create criteria and goals for prospective internship workers, increase the intensity of supervision, reconstruct the greenhouse, and create a slide desk.

Keywords: Hydroponic, NFT, Pakcoy, quality control, Statistical Quality Control, SQC

INTRODUCTION

The increasing demand for fresh and nutritious vegetables has spurred the advancement of innovative agricultural techniques, with hydroponics emerging as a viable solution. Hydroponics, a soilless method of growing plants, offers numerous advantages over traditional soil-based agriculture, including improved water efficiency, faster plant growth, and reduced risk of soil-borne diseases (Sardare and Admane, 2013). The Nutrient Film Technique (NFT) stands out for its efficient nutrient delivery and space-saving design among various hydroponic methods (Marina et al. 2021).

XYZ Hydroponic Farm, specializing in cultivating Pakcoy (*Brassica rapa chinensis*), has adopted the NFT system to meet the growing demand for high-quality leafy greens. Pakcoy, a vegetable widely appreciated for its nutritional benefits, is ideal for hydroponic cultivation due to its relatively short growth cycle and adaptability to controlled environments. Despite the promising potential of the NFT system, XYZ Hydroponic Farm has encountered challenges in maintaining consistent quality and controlling defect levels in its produce. The damage to yields that occurred reached 32%, exceeding the tolerance standard set by management policy of 10%. To address these challenges, it is essential to implement effective quality control measures. Statistical Quality Control (SQC) offers a robust framework for monitoring and managing the quality of agricultural products.

Statistical quality control (SQC) is a quality control method that can monitor, manage, analyze, and improve process performance using statistical methods (Ariani, 2020: 90). It is used to control the quality of a product from the initial process to the finished product and control the production process following predetermined quality standards (Meldayanoor et al., 2018: 133). According to Baktiar in Andespa (2020: 136), SQC is used to find product errors that cause the product to be damaged. Problem-solving in statistics includes two things: exceeding control limits if the process is under control or not

exceeding control limits if the process is out of control (Ariani, 2004: 54). By employing statistical techniques such as control charts and process capability analysis, it is expected that SQC will enable XYZ Hydroponic Farm to identify and control variability in the cultivation process, ensuring consistent quality and minimizing defects.

MATERIALS AND METHOD

The research was conducted at XYZ Hydroponic Farm, Sukamakmur, Bogor Regency, from March 2023 to June 2024. Quantitative data consists of the amount and level of hydroponic Pakcoy damage. Qualitative data collected are data related to information on the Pakcoy cultivation process, the causes of Pakcoy quality damage, and other data related to Pakcoy quality control in the cultivation process.

Data was collected through observations, interviews, and documentation. Observations include observing the cultivation process and quality control system of hydroponic Pakcoy. Data grouping of Pakcoy damage types is sorted based on the condition of leaves, stems, and Pakcoy shape and size. Interviews were conducted with the CEO, head of farm, and staff of XYZ hydroponic farm to obtain information about the company and its strategy regarding quality control. Documentation was conducted to obtain data using company documents. The data collected in the field was then processed using Microsoft Excel software as a Checksheet. The processed and collected data is in the form of a table and contains data on the date of collection, the amount of damage, the type of damage, and the total percentage of Pakcoy damage.

The analysis method used in this research is statistical quality control (SQC) to find product errors that cause damaged products. The SQC method requires tools to complete it: Pareto Diagrams, Control Maps, and Fishbone Diagrams. The triangulation method tests data validity using source and method triangulation.

RESULT AND DISCUSSION

The quality control carried out by XYZ Hydroponic Farm aims to meet the predetermined quality and reduce the number of damaged products, which includes activities from the cultivation process to post-harvest handling based on the company's quality standards (Table 1).

Quality control of Pakcoy in the cultivation process consists of preparing installations and net pots, rejuvenating Pakcoy, transplanting and enlarging Pakcoy, controlling pests, and controlling pH and nutrients (Figure 1).

Harvest and post-harvest control of Pakcoy is the last control carried out. Harvesting is conducted by carefully placing Pakcoy in a pile so the stems and leaves are not damaged. The harvested Pakcoy is then placed on top of the plastic container lid in a stacked manner and should not exceed two levels. After harvested, it is taken to the post-harvest handling area, where it is cleaned using a brush to remove bamboo powder and aphids and using scissors to remove leaves with holes on the edges, yellow or curled. The cleaned Pakcoys are then placed under the hydroponic installation to prevent them from rotting, after which the Pakcoys are weighed and packed. Before transport, the packaged Pakcoys are given a final check. Pakcoys that look damaged are then dismantled and replaced with new ones.

Table 1. Quality Standard and Defective Products of Pakcoy in XYZ hydroponic farm

Criteria	Qualified Product	Defective/Damaged Product
Leaves	1. Smooth green 2. Have more than four leaves	1. Yellowish 2. Torn 3. Curling 4. Perforated 5. Have less than four leaves
Stem	1. Not crushed 2. Not broken 3. Has less than four cut marks	1. Crushed 2. Broken 3. Has more than three cut marks
Shape and Size	1. Oval-shaped 2. Not etiolated 3. Upright 4. Weighs more than 30 grams and less than 75 grams	1. Not oval-shaped 2. Etiolated 3. Not upright 4. Weighing less than 30 grams and more than 75 grams

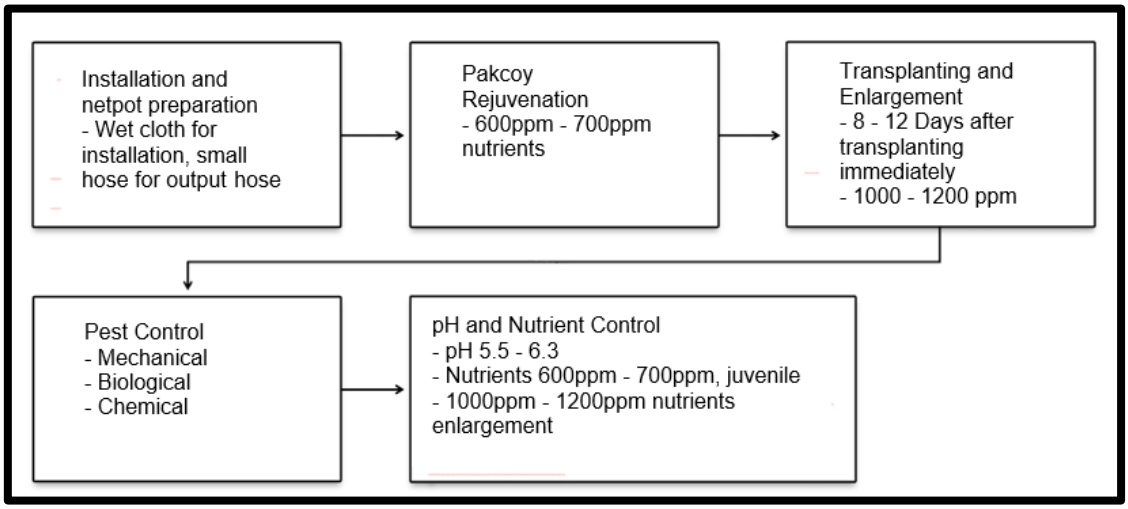

Figure **1.** Control Process of Pakcoy Cultivation

1. Types and Levels of Damage in Hydroponic Pakcoy

The types of Pakcoy damage include damaged leaves, damaged stems, and the abnormal shape or size of Pakcoy. The damaged leaves are indicated by yellowish color, torn, curled, perforated, and if it has less than four leaves (Figure 2a). Damaged stems are characterized by broken stems with more than three cut marks (Figure 2b). The abnormal shape and size of Pakcoy are characterized by a non-oval shape, etiolated, not upright, and weighing less than 30gr and more than 75gr (Figure 2c).

The damage level of Hydroponic Pakcoy

Data on Pakcoy damage types that have been recorded in company documents are then reprocessed using a Checksheet in the form of a table (Table 2) containing data on harvest dates, the amount of production of each harvest, the type of Pakcoy damaged, and the amount of damage.

Quality Performance of Hydroponic Pakcoy

Based on the level of damage obtained in Table 2 and Figure 2 (a,b,c), it is necessary to determine whether the state of hydroponic Pakcoy is under control or not. Analysis was conducted using a p-

control map chart because the data obtained is not constant in number. Control limits consisting of upper control limit (UCL) and lower control limit (LCL) can describe the high-quality performance if it does not exceed these limits. The p-control map chart is presented in Figure 3.

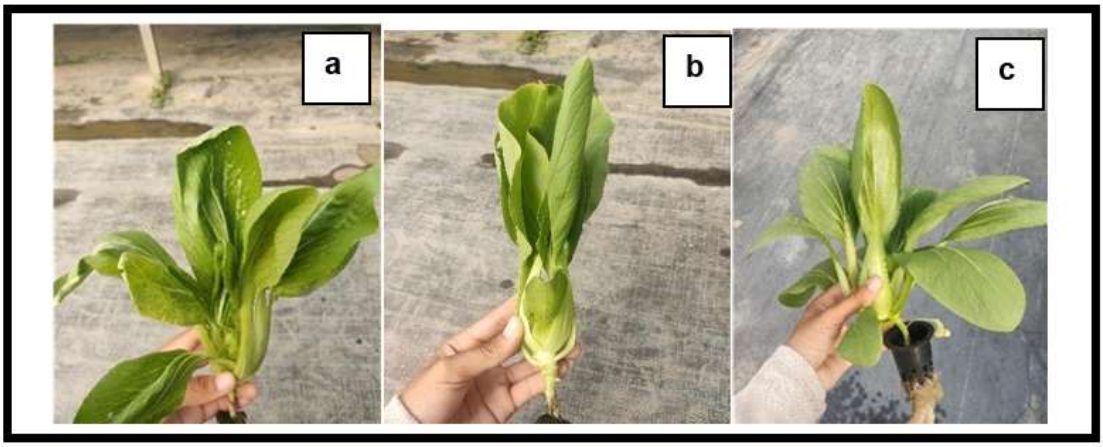

Figure **2**. Types of damaged Pakcoy: (a) damaged leaves; (b) damaged stem; (c) abnormal shape or size

Table **2.** Checksheet of damaged Pakcoy in XYZ Hydroponic Farm

No	Date	Total Produce (grams)	Total Damaged Pakcoy (grams)	Proportion	CL	UCL	LCL
1	09/03/2023	63475	9225	0,145	0,18	0,181	0,17
2	13/03/2023	68335	23335	0,341	0,18	0,180	0,17
3	16/03/2023	15135	5450	0,360	0,18	0,185	0,17
4	20/03/2023	43135	9635	0,223	0,18	0,182	0,17
5	23/03/2023	64920	8920	0,137	0,18	0,181	0,17
6	27/03/2023	91035	23035	0,253	0,18	0,180	0,17
7	30/03/2023	53915	11665	0,216	0,18	0,181	0,17
8	03/04/2023	40255	12755	0,317	0,18	0,182	0,17
9	06/04/2023	57935	17935	0,310	0,18	0,181	0,17
10	10/04/2023	48710	20710	0,425	0,18	0,181	0,17
11	13/04/2023	29300	11050	0,377	0,18	0,183	0,17
12	17/04/2023	60155	13655	0,227	0,18	0,181	0,17
13	27/04/2023	77000	18000	0,234	0,18	0,180	0,17
14	01/05/2023	107405	39405	0,367	0,18	0,180	0,17
15	04/05/2023	72725	35975	0,495	0,18	0,180	0,17
16	08/05/2023	33690	10180	0,302	0,18	0,182	0,17
17	11/05/2023	26410	14410	0,546	0,18	0,183	0,17
18	15/05/2023	15825	7825	0,494	0,18	0,185	0,17
19	01/06/2023	31390	5390	0,172	0,18	0,182	0,17
20	05/06/2023	68950	28734	0,417	0,18	0,180	0,17
21	03/08/2023	39000	7000	0,179	0,18	0,182	0,17
22	07/08/2023	56250	8000	0,142	0,18	0,181	0,17
23	10/08/2023	32000	6000	0,188	0,18	0,182	0,17
24	14/08/2023	37500	5000	0,133	0,18	0,182	0,17

25	21/08/2023	48250	7000	0,145	0,18	0,181	0,17
26	24/08/2023	49000	9000	0,184	0,18	0,181	0,17
27	28/08/2023	46750	4000	0,086	0,18	0,181	0,17
28	31/08/2023	64500	5000	0,078	0,18	0,181	0,17
29	04/09/2023	53750	5000	0,093	0,18	0,181	0,17
30	07/09/2023	39500	5000	0,127	0,18	0,182	0,17
31	11/09/2023	40000	6000	0,150	0,18	0,182	0,17
32	14/09/2023	34000	2000	0,059	0,18	0,182	0,17
33	18/09/2023	40500	2000	0,049	0,18	0,182	0,17
34	21/09/2023	30750	4000	0,130	0,18	0,183	0,17
35	25/09/2023	43500	1000	0,023	0,18	0,182	0,17
36	28/09/2023	43500	5000	0,115	0,18	0,182	0,17
37	02/10/2023	21500	2000	0,093	0,18	0,184	0,17
38	05/10/2023	46750	2000	0,043	0,18	0,181	0,17
39	09/10/2023	28500	5000	0,175	0,18	0,183	0,17
40	12/10/2023	41000	4000	0,098	0,18	0,182	0,17
41	16/10/2023	46500	4000	0,086	0,18	0,181	0,17
42	19/10/2023	46500	5000	0,108	0,18	0,181	0,17
43	23/10/2023	37500	5000	0,133	0,18	0,182	0,17
44	26/10/2023	46500	5000	0,108	0,18	0,181	0,17
45	30/10/2023	8350	2000	0,240	0,18	0,189	0,16
46	02/11/2023	28000	4000	0,143	0,18	0,183	0,17
47	06/11/2023	23750	1000	0,042	0,18	0,183	0,17
48	9/11/2023	39750	1000	0,025	0,18	0,182	0,17
49	13/11/2023	37500	3000	0,080	0,18	0,182	0,17
50	16/11/2023	56750	7000	0,123	0,18	0,181	0,17
51	20/11/2023	34250	5000	0,146	0,18	0,182	0,17
52	23/11/2023	33250	7000	0,211	0,18	0,182	0,17
53	27/11/2023	32500	5000	0,154	0,18	0,182	0,17
54	30/11/2023	23500	5000	0,213	0,18	0,183	0,17
55	04/12/2023	26250	4000	0,152	0,18	0,183	0,17
56	07/12/2023	33750	6000	0,178	0,18	0,182	0,17
57	11/12/2023	10250	5000	0,488	0,18	0,187	0,16
58	14/12/2023	38000	4000	0,105	0,18	0,182	0,17
59	18/12/2023	35000	5000	0,143	0,18	0,182	0,17
60	21/12/2023	25500	3000	0,118	0,18	0,183	0,17
61	26/12/2023	45150	8000	0,177	0,18	0,181	0,17
62	04/01/2024	62500	9000	0,144	0,18	0,181	0,17
63	08/01/2024	36500	5000	0,137	0,18	0,182	0,17
64	11/01/2024	27500	7000	0,255	0,18	0,183	0,17
65	15/01/2024	19000	5000	0,263	0,18	0,184	0,17
66	18/01/2024	7500	1000	0,133	0,18	0,189	0,16
67	22/01/2024	20500	5000	0,244	0,18	0,184	0,17
68	25/01/2024	27250	6000	0,220	0,18	0,183	0,17
69	29/01/2024	36250	5000	0,138	0,18	0,182	0,17
70	01/02/2024	26750	4000	0,150	0,18	0,183	0,17
71	05/02/2024	18250	900	0,049	0,18	0,184	0,17
72	08/02/2024	15500	800	0,052	0,18	0,185	0,17
73	12/02/2024	34250	3000	0,088	0,18	0,182	0,17
74	15/02/2024	52500	2000	0,038	0,18	0,181	0,17
75	19/02/2024	66500	5000	0,075	0,18	0,180	0,17

76	22/02/2024	57750	3000	0,052	0,18	0,181	0,17
77	26/02/2024	47500	3000	0,063	0,18	0,181	0,17
78	29/02/2024	50500	3000	0,059	0,18	0,181	0,17
79	04/03/2024	48600	5000	0,103	0,18	0,181	0,17
80	07/03/2024	16000	1000	0,063	0,18	0,185	0,17
81	11/03/2024	27750	1000	0,036	0,18	0,183	0,17
82	14/03/2024	43750	1000	0,023	0,18	0,181	0,17
	Σ	3298870	590989				
	ṕ	0,18					
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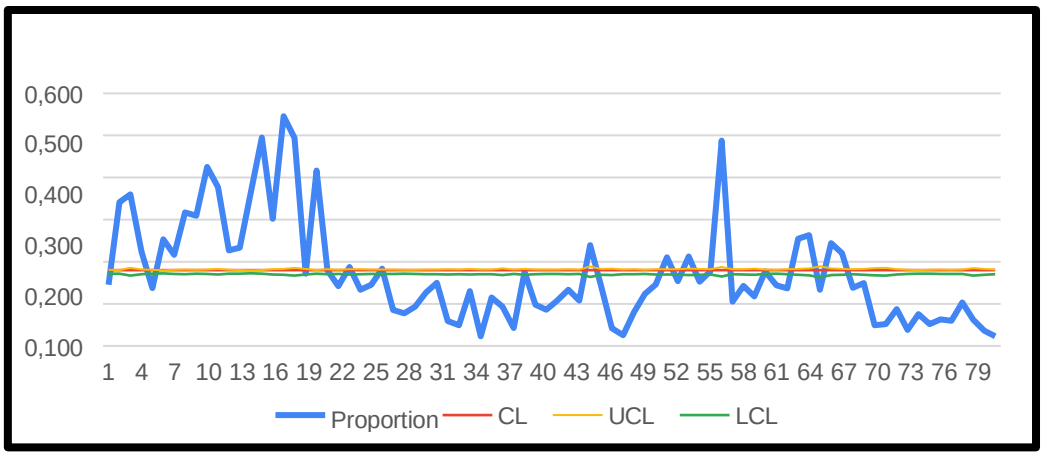

Figure **3**. Control p-map of Damage Pakcoy

Based on the p-control map presented in Figure 2, of the 82 points, there are only 6 points that are within the control limits, namely at the 19th point with the number of damaged Pakcoys of 5,390 grams, the 21st point with the number of damaged Pakcoys of 7,000 grams, the 26th point with the number of damaged Pakcoys of 9,000 grams, the 39th point with the number of damaged Pakcoys of 5,000 grams, the 56th point with the number of damaged Pakcoys of 6,000 grams, and the 61st point with the number of damaged Pakcoys of 8,000 grams. Meanwhile, 28 other points are outside the upper control limit, which means there is a high damage value compared to points in other months, while points outside the lower control limit indicate that there have been process changes. So, further analysis of the damage's causes must be undertaken.

2. Factors Causing Damage of Hydroponic Pakcoy

The p-control map of hydroponic Pakcoy shows that all three types of Pakcoy damage are still outside the control limits. Based on the Pareto diagram (Figure 3), damaged leaves and stems are the types of damage prioritized for corrective action. So, the next step is to determine the two causes of these types of damage. Analysis of the types of damage in this study using the Fishbone Diagram presented in Figures 4 and 5.

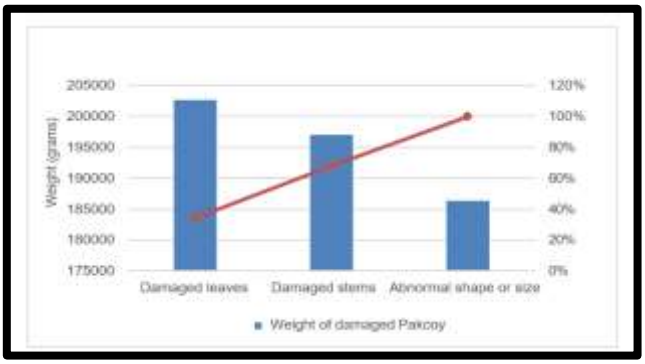

Figure 4. Pareto Diagram for Pakcoy Damage Level

The Damage Leaves

The damage leaves is the type of damage with the highest number found. Based on the observations and interviews, the causes of damaged leaves are presented in Figure 4.

Human factors cause defective products in the form of damaged leaves caused by lack of labor and lack of intern labor monitoring. Operating with only two labor staff and one head of the farm who has the task of managing a 1,500m^2 greenhouse with a total of 34,000 planting holes, the head of the farm divides the tasks carried out by all labor, such as transplanting, pest control, pH and nutrient control, harvesting, including post-harvest and record keeping. In addition, the two staff are also responsible for the seeding process.

Some interns from various departments and universities are involved in the hydroponic Pakcoy cultivation activities, usually consisting of 5 to 7 students, including non-agricultural students. Based on interviews and observations, the recruitment process of internship students is not based on knowledge criteria. The company also does not guide interns before going to the field or provide briefings whenever they work there. Labor staff and the head of the farm only show how to carry out production activities in the field, which internship students directly practice. The monitoring process is carried out by the head of the farm and staff only when the Pakcoy has been packaged. Due to the lack of labor, monitoring is not conducted intensively and consistently, especially during harvesting. This finding follows research conducted by Novianti et al. (2019: 141), which found that a small number of employees causes damage to defective leaves. In addition, the staff and head of the farm have multiple jobs, which include seeding, recording seedlings, recording the amount of raw materials, providing nutrients, controlling pH and nutrients, controlling pests, harvesting processes, packaging processes, and recording harvest results. These multiple jobs cause them to lose focus and lack the time to conduct intensive monitoring.

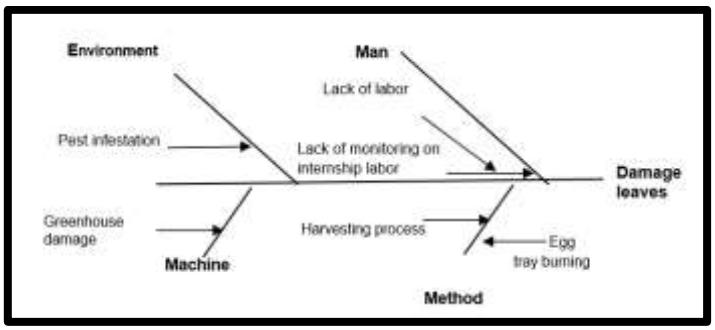

Figure **5.** Fishbone Diagrams of Damage Leaves

Based on observations and interviews, environmental factors causing leaf damage were *Plutella xylostela* and aphids. These leaf-destroying caterpillars, *P. xylostela*, usually attack young leaves aged 2 - 4 weeks. Pakcoy, which was attacked, showed perforated leaves and leaves traces like bites. During the day, the caterpillars will often hang under the Pakcoy plants. Aphids are usually found in the morning, especially during harvesting, and in the afternoon when pest control is carried out. Pakcoy leaves affected by aphids will show yellowing, curling, and wilting symptoms.

The method factor affecting product defects in leaf damage is the harvesting and pest control techniques conducted in XYZ Hydroponic Farm. The harvested Pakcoys are placed in a pile on the tray, causing the leaves to be damaged. Snagging leaves with other Pakcoy can also damage the leaves when taken from the pile. It is in line with the report from Salsabila (2022: 17) that the careless transfer of crops harvested can cause the leaves on vegetables to be damaged or perforated. One of the pest controls carried out on the farm is burning egg trays intending to kill aphids. Egg trays are placed under the plant installation or right under the plant and then burned. Egg trays placed too close to the bottom of the plant will cause Pakcoy leaves to burn due to air pollution. The effects of air pollution on plants impact morphological and physiological damage to plants, resulting in physical and chemical changes (Salsabila et al., 2020: 73).

Regarding the ‘machine’ factor that causes product defects, the greenhouse condition at XYZ farm has been damaged in several parts. The greenhouse has a bamboo foundation, a floor of soil covered with tarpaulin, and a plastic roof. Based on observations, the greenhouse's foundation is weathered, and there are holes in the walls and roof of the greenhouse at several points. The damage also makes it easier for pests to attack the plants inside.

The Damage Stems

Based on interviews and observations, three factors cause the damaged stems: humans, methods, and the environment presented in Figure 5.

The human factor that causes product defects in the form of damaged stems is labor carelessness. The interviews and field observations revealed that workers were less careful during the harvesting, sorting, and packaging. Taking Pakcoy to be sorted and packaged is still conducted roughly and carelessly, causing the damaged stems. This finding aligns with a report from Novianti (2019: 141) that stated that employees who are less careful in lifting plants during harvesting cause damage to the roots and stems of hydroponic vegetables. Labor negligence also contributes to defective products in the form of damaged stems. Data on the number of Pakcoy hydroponic vegetables harvested on D-day was sent from the evening of D-1 until noon at 11.00 a.m. Meanwhile, the transport process must be done at 1.00 p.m. so that workers are in a hurry to carry out the harvesting, sorting, and packaging processes. Every time the final check is carried out, Pakcoy packages are unpacked due to the damaged stems of Pakcoy found.

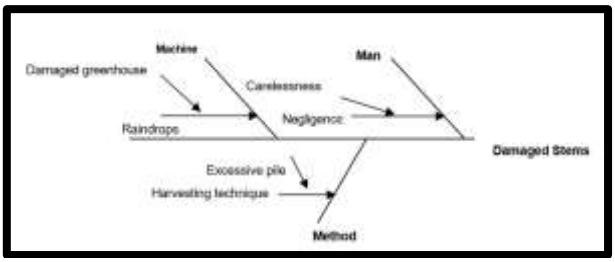

Figure **6.** Fishbone Diagrams of Damage Leaves

The method factor that causes damage to Pakcoy stems comes from the harvesting techniques carried out. Based on interviews and field observations, Pakcoy harvesting is done by stacking Pakcoy on top of plastic container lids following the Standard Operating Procedure (SOP), but the pile of Pakcoy should not exceed two levels. The short harvesting time, the large number of harvests, and the different harvest handling places cause the labor rush, so the harvesting process is carried out by stacking Pakcoy excessively. Non-optimal harvest handling causes defects in hydroponic vegetables (Salsabila, 2022: 17).

In terms of 'machine' factors causing product defects, based on interviews and field observations, heavy raindrops caused Pakcoy stems to be damaged and broken due to leaks in the greenhouse roof. The roof of the greenhouse is made of polyethylene film, which requires intensive care and maintenance and is easily damaged by sunlight (Kementan, 2021: 30). This is in line with research conducted by Komariyah (2024: 68), which states that the roof damage of a greenhouse will cause leaks so that plants are damaged by rainwater. Greenhouses with glass cover material are most efficient in transmitting light and can withstand excessive rain intensity (Kementan, 2021: 2).

3. Alternative Improvements

Based on the results of the analysis of factors causing damage to leaves, stems, and abnormal shapes and sizes caused by human, environmental, method, and machine damage, the proposed recommendations for improvements that can be made are presented in Table 3. The XYZ Hydroponic farm involves internship students carrying out the cultivation process from various universities and majors, including non-agricultural students who need to be monitored intensively. Since the head of the farm and staff already have multiple jobs, additional labor is needed to be responsible for consistent and intensive monitoring. This recommendation also follows research conducted by Komariyah (2024: 73). Training and guidance on pest control, effective harvesting, and engagement with internship students are proposed recommendations for improvement on human dan methods causes of damage. Training and guidance can be conducted fortnightly through discussion and practice between the CEO, head of the farm, staff, and internship students. Organizing hydroponic cultivation training is also an improvement recommendation to reduce hydroponic vegetable defects at PT SAS (Salsabila, 2022: 21).

Table 3. Proposed Improvements for Quality Control of Hydroponic Pakcoy in XYZ Farm

Causal Factors	Factor Causing The Damage	Recommendation for Improvements
Man	Lack of labor	Increase in labor
	Lack of caution in pest control	Training and technical guidance on pest control
Environment	Pest Infestation	Applying plant-based pesticide spraying
Method	Excessive piling	Training and technical guidance on harvest handling
	Harvesting Technique	Making slide desk
Machine	Greenhouse damage	Greenhouse reconstruction

Pests that cause damage to Pakcoy at XYZ Hydroponic Farm should also be controlled using plant-based pesticides. Based on research by Purwianshari and Suhartini (2017: 211), plant-based pesticides made from Tapak liman are effective in controlling leaf-destroying caterpillar pests by increasing pest mortality, shortening the larval phase to pupae, reducing the percentage of damage to Pakcoy plants, and increasing the wet weight of Pakcoy. Excellent spraying is conducted in the morning when the plant stomata open and the light level is still low so that it does not affect the nature or

structure of the plant-based pesticide (Purwianshari and Suhartini, 2017: 211).

The stacking of Pakcoy during the harvest process also causes Pakcoy to be damaged, so the proposed improvement recommendation is to make a Slide Desk. The Slide Desk aims to minimize Pakcoy damage because the Pakcoy harvesting process is no longer stacked. Through the Slide Desk, it is also possible to work effectively and efficiently and allocate responsibility for quality to the workforce.

Reconstruction of the greenhouse or total rebuilding is the next proposed improvement. Changing the foundation from bamboo to mild steel and glass roof are design options that can be realized in the future. Greenhouses with glass cover materials are most efficient in transmitting light and can withstand the intensity of rain; plus, mild steel can be used in the long term for 10 years and is suitable for use with glass coverings (Kementan, 2021: 26).

CONCLUSION

The level of damage to hydroponic Pakcoy that occurs at XYZ Farm shows uncontrolled damage with a high amount of damage; out of 82 harvest processes, there are only 6 points that are within the control limits with three types of damage, namely damaged leaves, damaged stems, and abnormal shape or size. Factors causing damage to hydroponic Pakcoy at XYZ Farm are humans, the environment, machinery, and other methods. The causes of damage include lack of labor, lack of care when controlling pests, pest attacks, greenhouse damage, and excessive piles in the harvest process. Proposed recommendations for improvements that XYZ Hydroponic Farm can make are to add labor, conduct training and guidance on pest control, apply plant-based pesticides regularly, conduct training and guidance on the harvest process, make a slide desk, and reconstruct the greenhouse.

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