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Characteristics of Mechanical Strength and Flexibility of Shallots Leaf

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Abstract

When operating drone sprayer, such as to distribute pesticides, downwash is the major cause of damage on the plants. Therefore, understanding the mechanical properties of plants are important to be able select the proper drone to use. In this research, characteristics of leaf strength and flexibility of two types of shallots were investigated, namely the Batu Ijo and Birma varieties. Research on the characteristics of the strength and flexibility of shallots was carried out from the 3rd to the 8th week for the Batu Ijo and 9 varieties of Birma, 100 samples each week. The strength of the leaf was measured by pulling the leaf until it breaks by attaching a thread to the base of the leaf which is pulled by a force gauge device. Then to measure its flexibility by pulling the top of the leaf with the thread that is pulled until it touches the ground surface. From this research, data on the strength characteristics of the leaves of the Birma variety 29 N that is much stronger than the Batu Ijo variety 8.9 N got obtained. Meanwhile, for the flexural characteristics, the Batu Ijo variety was 5 N with pressure P 0,113 N/cm² more flexible than the Birma variety 3.3 N with pressure P 0,087 N/cm². The minimum bending strength of the leaves for the two varieties F is almost the same, where for the Batu Ijo variety F 0.044 N with P 0.005 N/cm² and for Birma varety F 0.041 N with pressure P 0.009 N/cm². Based on the characteristics of this minimum bending, it becomes the basis for optimizing the design of the drone sprayer blade.

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1. Introduction

Shallots are a vegetable commodity that has many benefits and high economic value, and has good market prospects. Indonesia produced 1.98 million tonnes of shallots in 2022 (BPS 2022). Consumption of shallots by the household sector in 2022 has reached 831.14 thousand tonnes. Meanwhile, household participation in shallot consumption was 94.95%. The export value of shallots in 2022 reached US$ 4.18 million, a decrease of 41.1% (US$ 2.92 million) from 2021. The value of shallot imports in 2022 reached US$ 1.49 million, an increase of 88.2% (US$ 699.45 thousand) (BPS 2022).

Shallot production in Indonesia specifically over the last 10 years has continued to fluctuate, however with an increasing trend the assumption is that the need for shallot seeds is 1 ton/ha (BPS

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2022). However, shortages of seeds continue to be reported from year to year (Pangestuti and Sulistyaningsih 2011). In 2010, it was estimated that there would be a shortage of shallot seed bulbs amounting to 41% of the national requirement (Ismiyatiningsih and Sutardi 2010). The problems that farmers complain about are about varietal purity and the content of moler disease (Basuki RS. 2014).

To overcome the tendency of shallot plant diseases, farmers generally still use conventional pesticide spraying. It takes quite a long time and quite a lot of labor to spray pesticides and the costs are higher. Based on the research results of Yuantari et al. (2013) 85.2% of farmers do not pay attention to wind direction when spraying pesticides. Spraying operations are considered the most hazardous operations as operators have to deal with toxic chemicals and prolonged exposure (Borikar et al. 2022; Mogili and Deepak 2018; Shaw and Valkumar 2020). Drone Sprayers provides an effective method for such operations by reducing the operating time by at least about a third compared to conventional (Mat Su 2018).

One of the technologies that will be applied is drone sprayers, where utilization will focus on precision control of pesticides and fungicides to maintain soil nutrient conditions and farmer health. This is very important because the average rain fall that occurs in Humbang Regency every month in 2018 is 240.97 mm with an average rainy day of 18 days per month (BPS 2019). These weather conditions can cause a high tendency of pests and diseases in plants. So that the application of pesticides and fungicides on shallots is usually needed from the 3rd to the 8th week for the Batu Ijo variety and the 9th week for Birma after the planting period.

During operation drone sprayers on agricultural area Food Estate factors need to be considered downwash caused by the propeller drone sprayers. In aeronautics downwash is a change in the direction of air that is deflected by the aerodynamic action of a moving propeller (Leishman 2000). This is very important to pay attention to so that the downwash from the propeller does not damage the plants when applied.

Therefore, the purpose of this research to acquire the characteristics of the strength and flexibility of shallots using a tensile test tool for shallots leaf, so that the weakest leaf characteristics will be found. The weakest leaf based on the results of this research, will be the determine of research for blade design optimization, with the expectation that the weakest leaf can withstand downwash from drone sprayers, it can be assumed that all shallots leaf will be safe.

2. Materials and Methods

2.1 Time and Place of Research

This research was conducted from mid-December 2022 to March 2023. The design of the tensile test equipment was made at the Center for Aviation and Space Research Organization (ORPA) - BRIN

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(Badan Riset dan Inovasi Nasional) 6° LS – 106° BT Bogor. Planting and tensile test of shallots was carried out in Humbang Hasundutan District.

2.2 Cultivation of Batu Ijo and Birma Shallot Varieties

The Batu Ijo and Birma shallot varieties were planted in an area of 228 m^2 and 304 m^2 in Pollung District, Humbang Hasundutan Regency, respectively (Figure 2 and 3). Onion planting was using mulch to anticipate weeds. The beds will be formed for planting shallots that are suitable (Figures 2a and 2b) one bed 1.2 m wide by 6 lanes for the Batu Ijo variety and 7 lanes for Birma, 20 m long, 20 cm high, and the distance between the beds is 0.7 m. For the shallot plant beds, the distance between Batu Ijo and Birma varieties is 3 m. In the beds for each mulch with a size of 1.2 m, 5 planting holes was made. Measurement of the characteristics of the strength and flexibility of the Batu Ijo leek variety was carried out from the 3rd to the 8th week, while for the Birma variety until the 9th week after planting.

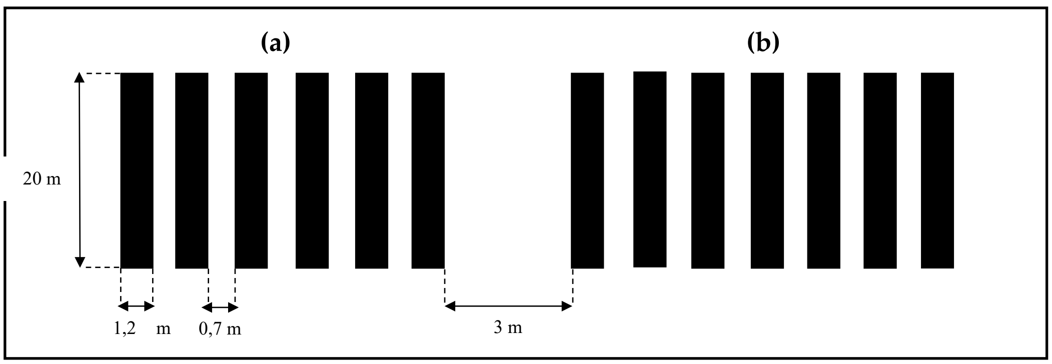

Figure 2. Birma Shallot beds of varieties (a) Batu Ijo, (b) Birma

Figure 3. Shallot planting area

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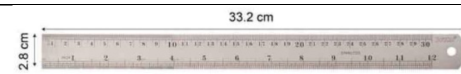
2.3 Measurement of the Characteristics of Strength and Flexibility of Shallots Leaf

The physical and mechanical characteristics of shallots leaves in term of strength and flexibility was recorded using a ruler, distance meter, and force gauge that are stated in Table. 1. Ruler and distance meter are tools that measured the change in distance that occurs when force is applied to the leaves. The distance meter measured distance using infrared radiation from a moving tool and a ruler which can be viewed manually, hoping that with these two tools the measurements of the distance will be more accurate. The force gauge is a tool that measures the amount of force needed to pull the leaves.

Table 1. Measuring tool for testing shallots leaves

Number	Tools	Quantity	Picture
1.	Ruler 30 cm	3 (Units)	
2.	Distance meter	1 (Unit)	
3.	Force gauge 20 N Aliyiqi AMF-20 China	1 (Unit)	

The strength and flexibility characteristics of shallot leaves (Figure 4) were recorded by applying parallel stems to the side of the shallots, then rigs got positioned in opposite of the stalks and leaves. There was force gauge on rigs to measure the amount of force needed to pull the leaves. Ruler and distance meter got positioned under force gauge to measure the distance of shifts when a force is applied. Sliding rigs were used to shift rigs when pulling leaf tests was going to be done. With this measurement, the characteristics of shallots in terms of strength and flexibility will be known, so that it becomes the basis for designing aerodynamics and propeller structures drone sprayers which does not damage the leaves.

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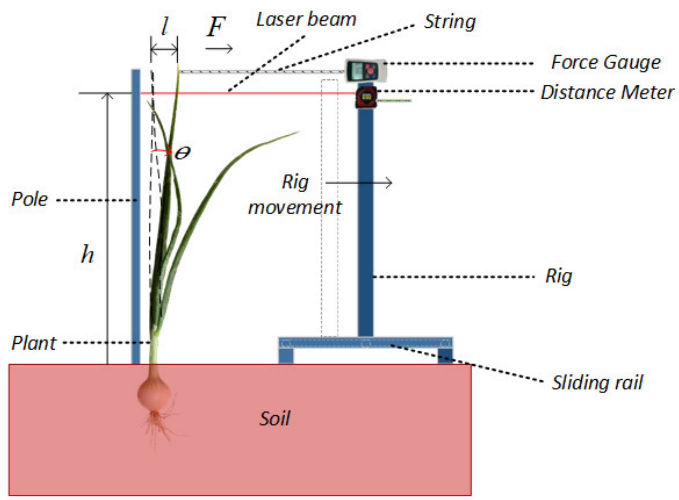

Figure 4. Methods for measuring the strength and flexibility characteristics of shallot plants

Shallot leaves were tested for tensile as many as 100 samples every week starting from the 3rd week. The strength of the leaf was measured by pulling the leaf until it breaks by attaching a thread to the base of the leaf which is pulled by the device force gauge. Then measured the bending by pulling the shoots of leaves with the string pulled by force gauge. Force (F) that happens when the thread attached to the leaf will be measured by force gauge. This force will cause the leaf to change the angle θ which can be calculated from the change in distance (l) by distance meters. The Height (h) namely the distance of the withdrawal point from the ground to the end of the leaf which will later be pulled until it touches the ground. Assuming a change in horizontal distance which is small then the change in angle θ can be calculated:

$$\theta = \arctan\frac{l}{h} \tag{1}$$

The force was designed to always be horizontal which will be pulled by a mechanical rail on rigs so the normal force can be calculate:

$$F_n = F\cos\theta \tag{2}$$

The area A of the onion is found using the formula for the area of the tube cover by multiplying the diameter d and height h of the shallot's leaves, which is as follows:

$$A = \pi x d x h \tag{3}$$

After obtaining the characteristics of the strength and flexibility of shallots leaf for both the Batu Ijo and Birma varieties, a propeller can be designed drone sprayers with downwash which is safe to apply to shallot plants.

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2.4 Shallots Leaf Tensile Test Equipment

The design of the characteristic tensile test tool for shallots was adapted to the height of shallots that started from the 3rd to the 8th week for the Batu Ijo variety and the 9th week for the Birma variety. This test tool (Figure 5) was consisted of 4 variations in height, namely 30, 40, 50 and 55 that took the height of the leaves from the 3rd week to the 8th and 9th week of the leaf planted season. Then force gauge (Figure 6) was used to measure the force that occurs when carrying out a tensile test on leaves both for strength and flexure tests. Changes in distance that occured were measured in two ways (Figure 6 and 7), namely by digitally used a tool distance meters and manually in reserved with a ruler applied to the base of the tensile tester. A thread is also tied between force gauge and leaf when applying leaf strength and flexure test.

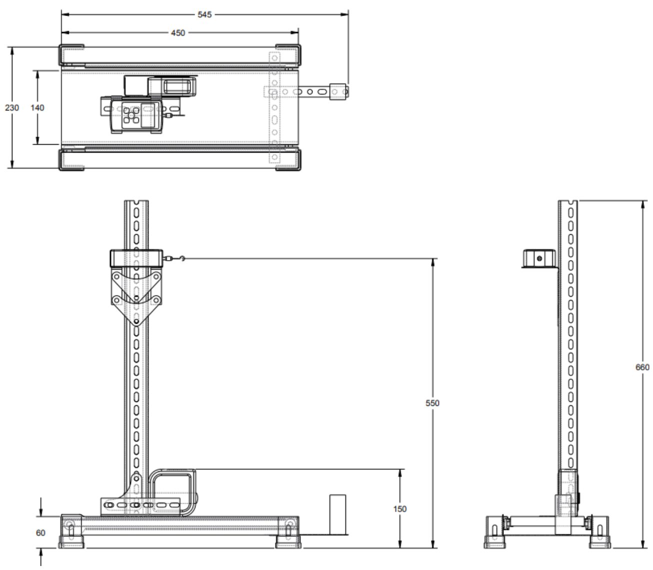

Figure 5. Dimensions of the shallots leaf tensile tester

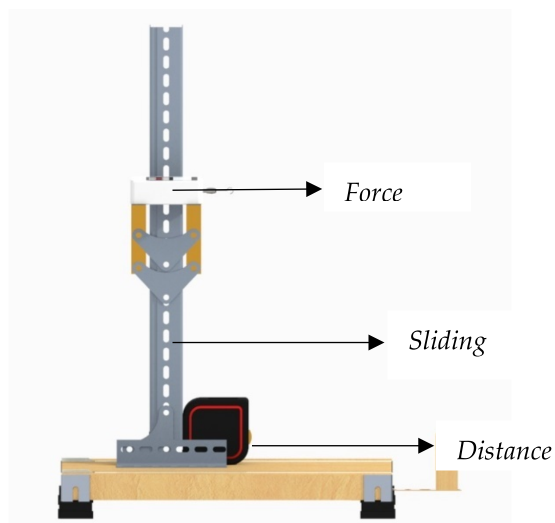

Figure 6. 3D shallots leaf tensile test equipment

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Figure 7. Shallots leaf Onion tensile test equipment

The strength characteristics of shallots leaf (Figure 8) got measured using threads tied parallel to each other force gauge and shallots leaf, where to test the strength characterization threads are tied to the base of the plant above the soil surface. Altitude position force gauge with the thread tied to the base of the shallots leaf must be parallel. The shallots leaf was pulled with the sliding rail slowly until the shallots leaf was cut off, so that when the shallots leaf started to be pulled until it was cut off, the amount of force *F* required is recorded.

Figure 8. Measurement of the strength characteristics of shallots leaf

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Measuring the bending characteristics of the shallots leaf (Figure 9), the threads were tied at the end of the leaves where the height of the leaves was recorded, then the height force gauge got positioned parallel to the height of the shallots leaf to be measured. Then the tip of the shallots leaf was pulled with a sliding rail until it touched the ground. When pulling, the magnitude of force *F* was recorded until the tip of the shallots leaf touched the ground.

Figure 9. Measurement of the flexibility characteristics of shallots leaf

3. Results and Discussion

3.1 The Results of the Strength Characterization of Shallots Leaf

The following are the results of the research of the strength measurement of shallots for the Batu Ijo variety which were measured for 6 consecutive weeks and for the Birma variety for 7 consecutive weeks, where each variety was examined starting from the 3rd week. Every week, 100 samples of shallots leaf were measured to measure the strength characteristics of each shallot variety. From this measurement, the maximum and minimum forces are obtained to be able to pull the leaf until it breaks.

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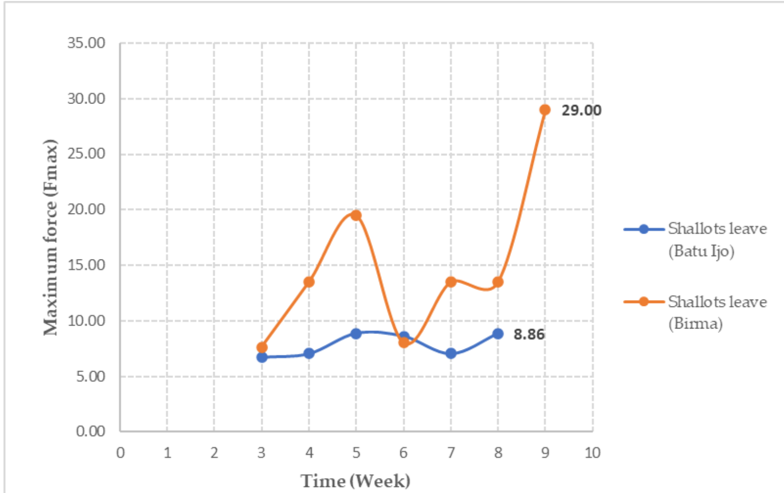

Figure 10. Maximum leaf tearing force of different shallots

The graph (Figure 10) shows the results of measuring the characteristics of the maximum strength of the two leek varieties every week. From the graph, it can be seen that the strength of the leaves with non-linear growth every week, such as the Batu Ijo, the maximum force F is quite high in the 5th week but in the following week it drops drastically. The very high rainfall factor in the 6th and 7th weeks causes the leaves to turn yellow due to fungus, so it requires quite serious treatment. So starting from the 8th week, the health of the leaves continues to improve until the 9th week. The maximum strength of the Batu Ijo variety was 8.86 N at the 8th week, while for the Birma variety it was 29 N at the 9th week, so the strength characteristics of the Birma variety of shallot leaves were much higher than the Batu Ijo variety.

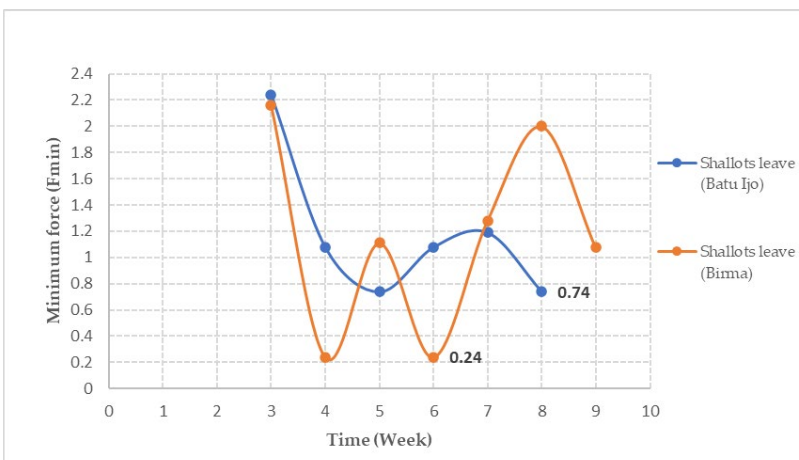

Figure 11. Minimum leaf tearing force of different shallots

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The minimum force as in the graph (Figure 11) also varies greatly due to the non-uniform size of the leaves. The minimum force for the Batu Ijo variety was 0.74 N at the 8th week and for the Birma variety it was 0.24 N at the 6th week, so that the minimum force characteristics of the Batu Ijo variety was stronger than those of the Birma variety.

3.2 The Results of the Flexibility Characterization of Shallots Leaves

The following are the results of the flexural measurement of shallots for the Batu Ijo variety which were measured for 6 consecutive weeks. Every week, 100 samples of leaves were measured for the measurement of the flexural characteristics of 100 samples.

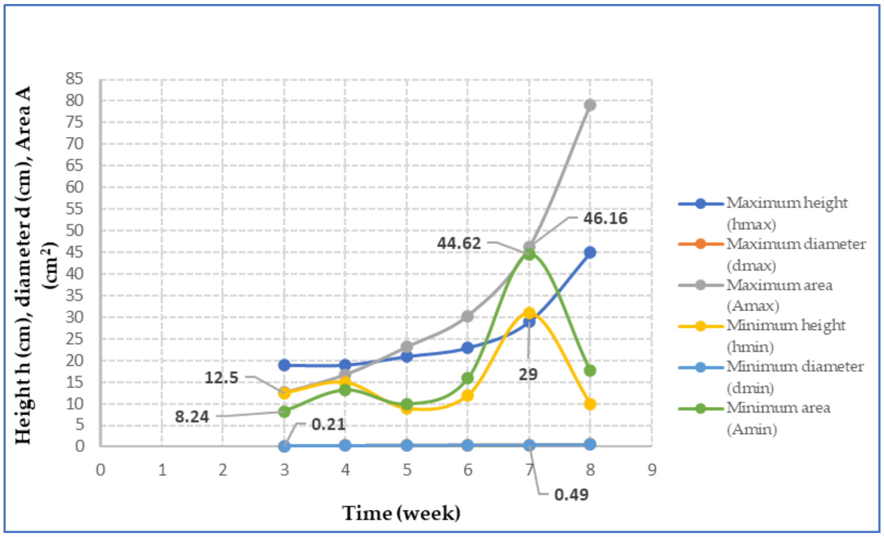

Figure 12. Maximum and minimum physical size of shallots leave (Batu Ijo)

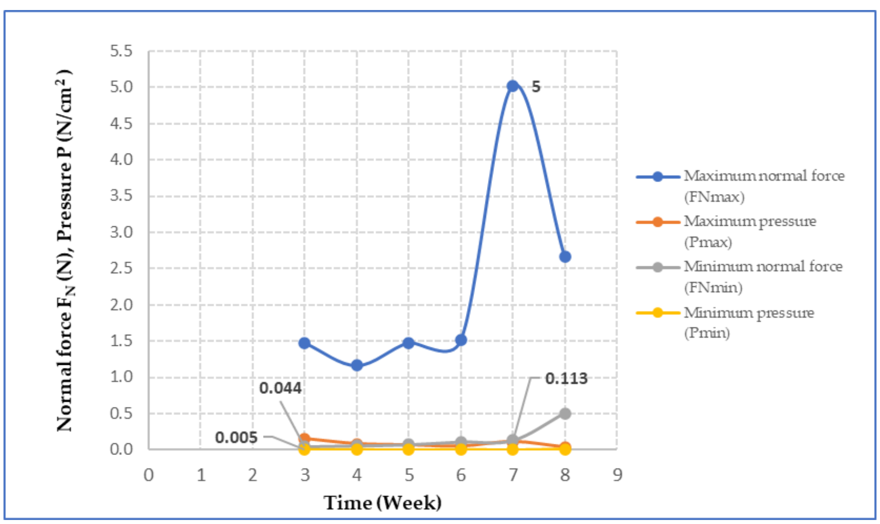

Figure 13. Force and pressure of shallots leave (Batu Ijo)

The results of measurements of the characterization of the Batu Ijo Leaves as in (Figure 12), for the maximum physical development of leaves, both height (*h*), diameter (*d*), and area (*A*), the growth of shallots increased linearly every week. However, the minimum physical size of the leaves in the 8th week is smaller than in the 7th week, this was due to uneven physical growth and could also be because it was starting to approach the harvest period. Some of the leaves were starting to turn yellow as a sign that the onions were already ripe and could be harvested in the near future, so this condition also greatly influenced the *F* applied as in (Figure 13) where the *F* in the 7th week was higher than week 8thTherefore though the size of the leaves is 45 cm taller in the 8th week, the force required was much smaller than in the 7th week. The maximum flexural strength (Figure 13) of the Batu Ijo leaf variety is *F* 5 N with apressure *P* 0.113 N/cm^2 in the 7th week with a maximum leaf (Figure 12) height of *h*29 cm, a diameter of *d* 0.49 and a leaf area of *A* 44.62 cm^2. The minimum flexural strength (Figure 13) of the Batu Ijo variety *F* 0.044 N with a pressure of *P* 0.005 N/cm^2 in the 3rd week with a leaf (Figure 12) height of *h* 12.5 cm, a diameter of *d* 0.21 and a leaf area of *A* 8.24 cm^2.

The results of measurements of the characterization of the flexural shallots for the Birma variety which were measured for 7 consecutive weeks. Every week, 100 samples of leaves were measured for the measurement of the flexural characteristics of 100 samples.

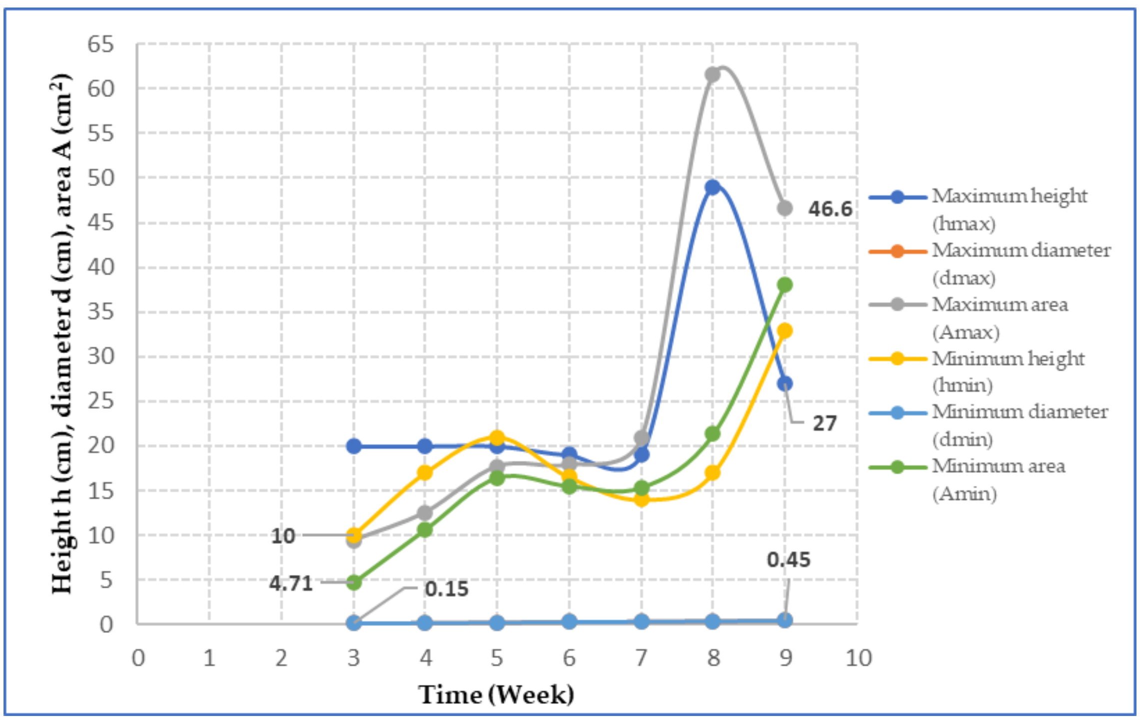

Figure 14. Maximum and minimum physical size of shallots leave (Birma)

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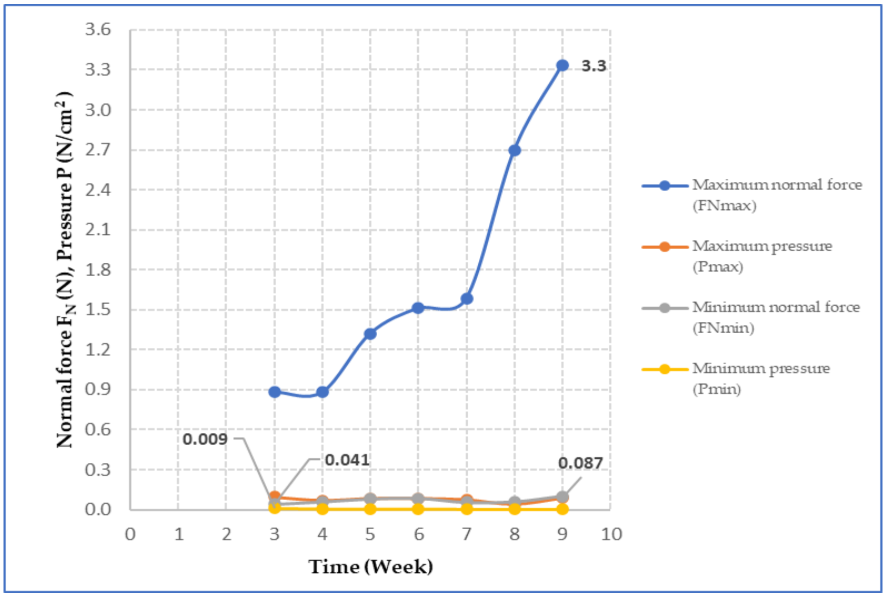

Figure 15. Force and pressure of shallots leave (Birma)

The results of measurements of characterization of the Birma Leaves as in (Figure 14), the maximum growth in height and diameter was drastically high in the 8th week, but decreased quite significantly in the 9th week, this was due to the maturity of the leaves approaching harvest time, so the leaves began to turn slightly yellow so the leaves began to weaken. However, the minimum h continues to increase from week 3 to week 9 because there are still quite a lot of variations of healthy leaves. So in the 9th week the size of the shallots leaves was still found to be the highest with the force required being also greater than in previous weeks. The maximum flexural strength (Figure 15) of the Birma variety is F 3.3 N with a pressure of P 0.087 N/cm^{2}in the 9th week with a leaf (Figure 14) height of h27 cm, a diameter of d 0.45, and a leaf area of A 46.6 cm^2. The minimum flexural strength (Figure 15) of the variety Birma was F 0.041 N with a pressure P of 0.009 N/cm^2 in the 3rd week with a leaf height of 10 cm, a diameter of 0.15 and a leaf area of A 4.71 cm^2.

4. Conclusion

The force required for the shallots leaves flexural characterization is much smaller than the strength characterization. For this reason, the drone blade will be designed based on the minimum bending value obtained, so it can recommend a force F that is still safe to apply, where the smallest minimum flexural characterization required is for the Batu Ijo variety, F 0.044 N with a pressure of 0.005 N/cm^2. So, the design Balde with a downwash effect that is still safe to apply to leaves for both varieties must be at a pressure below 0.005 N/cm^2. At a pressure of 0.005 N/cm^2, it is assumed that the flexibility of the shallots leaves is the weakest, therefore we can obtain the leaves parameters which will be entered into the CFD simulation for the design of the drone sprayer blade, namely for the Batu Ijo variety with a height of red onion leaves *h* 12.5 cm, diameter *d* 0.21, and leaf surface area *A* 8,24 cm^2. Assumption if the weakest leaves are able to withstand the downwash from the drone sprayer, it can be assumed that all the leaves will be safe for the application of the drone sprayer that will be designed.

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