Pulverization of sweet potato vine at different mower speeds

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Abstract. The effects of different mower speeds (2358, 2440 and 2553 rpm) and different knife angles (30°, 40° and 50°) on sweet potato vine pulverization were studied. The results indicated that all the treatments were significant at \( p < 0.05 \) and \( p < 0.01 \) significance level for the pulverized percentage of sweet potato vine. The 30° knife angle gave the best result with highest vine pulverized percentage of 54.60\%, and a mower speed of 2553 rpm had the finest vine pulverized percentage of 46.99\%. The best performance for interaction effect between knife angle and speed of mower was achieved by the 30° knife angle and a mower speed of 2440 rpm resulting in an average percentage of 61.27\% of pulverized vine.

1. Introduction

A review was conducted on different types of mowers, knives typically used to cut the vines and leaves and concluded that the flail type and vertical type mowers sweeping is most effective in the removal of vegetation [1]. Cutting and grass cutting has many variables that have an impact on crushing and some of the important variables are the cutting speed and the percentage of moisture from the vine, and there is a need to establish a model of cutting mechanics and to relate knife parameters to forage material properties [1, 2].

The results indicate that optimisation of cutting speed and blade oblique angle will result in significant energy savings and increased efficiency of miscanthus harvesting machinery [3]. Justin et al. [4] indicated from earlier studies that cutting speed and blade configurations play a significant character in crop harvesting. Variety, knife bevel angle, moisture content and cutting speed are the main factors affecting shearing strength and energy of the wheat stem [5].

The information available is shown to be diverse and largely empirical but probably sufficient for conventional cutting heads to have been developed to near optimal form. Research shows that blades used in forage chopping should have a blade angle in the range 30°- 40° with a rake angle of 10°- 20°, cutting at speeds up to 30 m/s. The optimum radius of the cutting edge is approximately 0.05 mm. A rotary mower has shown minimum power requirements at blade angles between 25° and 30°. A similar result suggests minimum energy requirements for a 25° angle, even though they found slight difference over a range 25°-50° [1], and some have studied the effect of rake angle and found that an angle of 30° gave least energy.

O'Dogherty [1], reported from other studies that a continuous reduction of specific energy with increasing rake angle for maize stalks which indicated that a value of at least 30° was required with an optimum at approximately 50°. Most of the investigations on the effect of blade cutting speed on
single stems have been concerned with impact cutting, and found a relatively slow linear fall of about 25% in specific energy for assemblages of stems as velocity was increased from 20 to 60 m/s. In both laboratory experiments on single stems and field experiments on mowers, the evidence is that a high impact velocity is required. Typical velocities employed by disc and rotary mowers are in the range of 71-84 m/s [1].

The results for many studies [6, 7] indicate that all the treatments were significant at 99% significance level for the grass leave area and the length of stem. The best results obtained for the mower speeds at 2500 rpm and 2700 rpm had the best average value of 9.47 and 6.19 cm² for the leave area and 15.83 and 17.82 cm for length of stem, respectively.

Another study for [8] showed that the best results were at a mower speed of 2500 rpm and 20.37% of grass moisture content which resulted in average values of 81.03% for the percentage of the leave area and 82.08% for the percentage of the length of the stem. Kakahy et al. [9], results indicated that all the treatments had significant effects at 99% significance level for the percentage of grass leave area and the percentage of length of stem.

Study by Jorge et al. [10] found that the power required for pineapple fields shredding increases with the feeding speed and the cutting apparatus angular velocities. Impact cutting of stems required critical speeds of 15 and 25 m/s for the sharp and blunt blades, respectively, and the results for 5 and 20 m/s cutting speed show that there was a reduction in the percentage of uncut stems as rake angle was increased over the range -30° to +45° [11].

The minimum cutting speed increased from 12.9 to 18.0 m/s for a knife rake angle range of 20-60° as the knife bevel angle was increased from 30 to 70°, and a blade speed of 25 ms⁻¹ was essential to slash most forage material without complexity, also the flail-type devices tended to show a minor reduction in cutting energy requirements as the knife speed increased [12, 13].

Further study of the concept of blade usage is required before it may be usefully applied to the design and operation of rotary mowers [14]. There are requirements for additional, cutting mechanics and for further studies of the cutting action of blades, and there is a need to create a model of cutting mechanics and to relate knife parameters to forage material properties [15, 16].

2. Methods

The study was conducted at the Department of Biological and Agricultural Engineering Laboratory, Faculty of Engineering, University Putra Malaysia, to investigate the effects of three different knife angles (30°, 40° and 50°) and three different speeds (2358, 2440 and 2553 rpm) of a mower on sweet potato vine slashing (pulverizing), at 36.15% moisture content, wet base (w.b%).

Data were analyzed statistically using ANOVA (analysis of variance) and the least significant difference LSD calculated at p < 0.05 and p < 0.01 (probability of obtaining a test statistic) to estimate the differences between the averages.

3. Results and Discussion

Table 1 and 2 and figure 1, 2, 3 and 4 indicate that all the treatments had significant effects on the percentage of vine passing through the sieve (< 28 mm²) at p < 0.05 and p < 0.01. The 30° knife angle gave the highest pulverized vine of 54.60% passing through the sieve while the lowest percentage of 36.84% was by the 50° knife angle. The 2553 rpm mower speed gave the highest percentage of vine passing through the sieve at 46.99%. It is well known that speeding up the cutterhead provides a shorter cut for the vine, the results are have a good agreement with conducted results by [6, 7].

On interaction effect between the knife angles and mower speeds, the best result was by the 30° knife angle with 2440 rpm mower speed giving 61.27% of the percentage of vine; in the meantime the lowest one at 35.71% was by the 50° knife angle at 2440 rpm mower speed. The results agree with the founding of [1, 6, 7, 16].
Table 1. Analysis of variance (ANOVA)

| Source of variation ( S.O.V) | Degree of freedom (d.f) | Percentage of vine passing through the sieve (<28mm²)% |
|------------------------------|------------------------|-------------------------------------------------------|
| Duplicates                   | 2                      | 723.91<sup>a</sup>                                    |
| Transactions                 | 8                      | 2.2409<sup>b</sup>                                    |
| Angles of knife (a)          | 2                      | 116.01<sup>a</sup>                                    |
| Speeds of mower (v)          | 2                      | 0.5697                                                |
| Interaction between (a, v)   | 4                      |                                                       |
| Experimental error           | 16                     |                                                       |
| Total                        | 26                     | L.S.D1%=1.5919,                                       |
|                              |                        | L.S.D5%=1.076                                         |

<sup>a</sup>significant at p < 0.01 level.
<sup>b</sup>significant at p < 0.05 level.

Table 2. Factors influencing the percentage of vine passing through the sieve (%).

| A            | 2358 | 2440 | 2553 | Mean<sup>a</sup> |
|--------------|------|------|------|-------------------|
| 30°          | 53.16| 61.27| 49.37| 54.60             |
| 40°          | 49.57| 41.01| 53.21| 47.93             |
| 50°          | 36.44| 35.71| 38.38| 36.84             |
| Mean<sup>b</sup> | 46.39 | 46.00 | 46.99 |                  |

<sup>a</sup>Knife angles.
<sup>b</sup>Mower speeds.

Figure 1. Effects of the treatments on the percentage of vine passing through the sieve (<28mm²).
Figure 2. Effects of the interaction on the percentage of vine passing through the sieve (< 28mm²).

Figure 3. Effects of the speeds of mower on the percentage of vine passing through the sieve (< 28mm²).

Figure 4. Effects of knife angles on the percentage of vine passing through the sieve (< 28mm²).
4. Conclusion
The study indicated that the best result on pulverization was achieved by the 30° knife angle at 2440 rpm mower speed, and there was significant difference of all the studied characters. Other mower speeds and knifes angle will be deliberated in the future.

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