INTRODUCTION

Alfalfa has a unique place in the hay crop because of its high protein and carotene content (4). As the total hay loss in the United States averages 650 million dollars per year, efforts are being made to minimize these losses.

Farm crop losses that occur during harvest depend on the conditions of the crop at the time of harvest and on the type of machinery used for harvesting. An extensive review of the losses that occur in the field during drying is reported by Hall (3).

Daum (2) reported on the factors affecting leaf shattering of hay during mechanical handling. His experiment was in two phases: (a) a determination of the tensile strength of the leaf petioles; and (b) an analysis of the effects of impact, compression, and acceleration on leaf loss. Pederson and Buchele (9) indicated the existence of losses due to fermentation. They showed that the losses occur in the time interval between cutting and storing of hay. They further indicated that 90% of the transpired water leaves the plant through the stomata, while 10% passes through the water-resistant cuticle of the leaves and stems. Many others (5, 7, 8, 11) studied the properties of the stem only.

EXPERIMENTAL METHODS

The present investigation is to determine how the stem-leaf moisture difference affects leaf separation from the plant when it is subjected to various mechanical forces.

The experiment was conducted on alfalfa plants at three different stages of maturity: (a) early bud stage; (b) first-flower stage; and (c) full-flower stage. The moisture content of each sample was found on a wet basis (WB) for both stem and leaf part, using the following relation:

\[
\text{% Moisture content} = \frac{\text{wet wt} - \text{dry wt}}{\text{wet wt}} \times 100 \quad \text{(WB)}
\]

The above weights were determined to an accuracy of 0.0001 g (error within ±1% of the sample moisture content). Drying was accomplished by placing the sample in a Fischer isotemperature oven set at 280°F (137.8°C) for 2 h. The dry-weight loss of the sample was less than 0.05% of the weight of the samples.

The mechanical forces required to separate the leaf from the plant at various stem-leaf moisture difference levels were determined experimentally using the methods of MacAulay and Bilanski (6) and Raghavan and Bilanski (10). The various parameters considered were axial force, bending force, vibration, and tumbling. The number of test samples required were collected from the field using a random sampling technique (1).

Axial Force Test

A constant-rate loading mechanism (6) was used to find the force for this test. In this apparatus, the test plant was held by a rubber-faced clamp. A clip at the end of the chain was used to hold the desired leaf. To increase the load on the leaf, the overhang of the chain was increased until it separated from the plant.

During the axial force test, each stage of maturity was further classified into three groups depending on leaf size. The axial force required to separate the leaf from the stem was determined for each of these groups. A total of 360 samples were tested for each stage of maturity.

Bending Test

In this test the petiole was considered to act as a cantilever at the stem, and force was applied at the loading point (point where the leaves are connected to the petiole) by a constant-rate loading mechanism. When the petiole was broken from the stem, the load was recorded as the ultimate bending force. This test was conducted for samples with various stem-leaf moisture differences. For each stage of maturity, 480 samples were tested.

Vibration Test

Each test sample was vibrated at various frequencies for periods up to 1.25 h. A pan located beneath the sample collected any leaves that were shaken loose. Percent leaf loss was then calculated from the weight of the leaves shaken loose and the sample weight. This test procedure was repeated for various stem-leaf moisture difference values. A total of 60 samples were tested for each stage of maturity during this test.

Tumbling Test

The samples were weighed and placed in the rotating drum for a test period of 5 min. After the test, the stem portion of the plant was carefully separated from the leaves that were broken from the stem during the treatment. Each portion of the sample was then weighed on a Mettler balance to determine the percentage of leaf loss. A total of 180 samples were tested at three different stages of maturity.
RESULTS AND DISCUSSION

The axial force (in grams) required to separate the leaf from the stem is listed in Table I. The values given in the table are the mean values for each stage of maturity of a particular leaf size. Significance level is shown for each of these values. At every stage of maturity, alfalfa leaves were less securely connected at higher values of stem-leaf moisture content difference than at lower values. Test results indicate that the variation in stem-leaf moisture difference at each stage of maturity was similar. The study reported by Daum (2) did not consider the effects of moisture content difference between stem and leaves on tensile force evaluation of leaf petiole. However, he reported that the tensile strength decreases with the decrease in moisture content of the plant. This statement is compatible with the results of the present study.

The bending test results were analyzed from the test data. This analysis indicated the bending force to be independent of stem-leaf moisture difference for all stages of maturity.

The leaf loss information at various stem-leaf moisture difference values for the vibration test were used to plot Figure 1. The linear relation shown in Figure 1 was the result of regression analysis. The coefficients of determination ($r^2$ value) for early bud stage, first-flower stage, and full-flower stage of maturity were found to be 0.41, 0.63, and 0.67, respectively.

For each stage of maturity, leaf loss increased linearly with the increase in stem-leaf moisture content difference. Similar results were found during the tumbling test. The equations for each stage of maturity, along with their coefficients of determination ($r^2$ value) are given in Table II. The analysis of variance of leaf loss for both vibration and tumbling test are listed in Table III. The leaf loss during vibration and tumbling tests was found to be highest for full-flower stage, as compared to first-flower and early bud stage of the alfalfa plant.

CONCLUSIONS

1. The stem-leaf moisture content difference affects leaf removal in tension. When the stem-leaf moisture content difference is minimal, the leaf is well secured to the plant. This behaviour exists for all stages of maturity of the alfalfa plant.

2. During the bending test, the bending force needed to separate the leaf from the plant was found to be independent of stem-leaf moisture differential.

3. Percent leaf loss due to vibration increases linearly with the increase in stem-leaf moisture differential. The loss is higher for the mature plants.

4. Stem-leaf moisture content difference also affects leaf loss during tumbling. The percent leaf loss increases linearly with the increase of stem-leaf moisture differential.

SUMMARY

The effects of stem-leaf moisture differential were examined for leaf separation from an alfalfa plant subjected to different forces such as tension, bending, vibration, and tumbling at each of the three stages of maturity. Overall results indicate an increase of leaf loss due to mechanical forces at higher stem-leaf moisture different values.
ACKNOWLEDGMENTS

The authors acknowledge the help of Dr. Harper, Agricultural Engineering Department, during the preparation of this paper. The excellent job of typing this paper by Mrs. Cinde Whitman is sincerely appreciated.

REFERENCES


