A simply-constructed high performance tobacco leaf stripping machine with a pair of counter-rotating stripping rollers has been developed and proved to be of practical value through the performance tests made on five tobacco farms in Japan. The results confirmed that the leaf stripping machine strips tobacco leaves at least twice as efficiently as manual stripping assuming that the leaves do not need to be oriented in any particular way. There were no observed incidences of leaf injury. The stripped leaves were able to be sorted into any number of grades by placing the proper number of partitioning plates under the stripping rollers. The use of this new machine would be particularly advantageous for stalk-cut tobacco cured with more leaves than conventional practices.


INTRODUCTION

Burley tobacco and some of the native Japanese varieties are stalk-cut and cured in green houses or curing barns. The cured tobacco leaves are stripped from the stalks and sorted into several grades in preparation for market. Conventionally, this separation of tobacco leaves is performed manually. A time study was conducted at the test farm owned by Japan Tobacco Inc. The total labor requirement for producing burley tobacco was estimated to be 1,963 hr/ha, in which harvest and post-harvest labor requirement was 1,534 hr/ha including 308 hr/ha for stripping operation. A growing need for cost reductions of this particular operation has led to the development of the high performance leaf stripping machine described in this paper.

In the United States, several attempts have been made at reducing the labor requirements for stripping stalk-cut tobacco. This has been instigated as a result of rising labor costs and the reduction in availability of seasonal labor. Morrison et al. (3) investigated how critical were the grading demands for burley tobacco. Grading by stalk position was preferred to grading by visual inspection of individual leaves themselves. It was indicated that the actual stalk length system would be a better indication of leaf grade than the percentage of stalk length system for use with the mechanical device. In conjunction with manual stripping, Morrison and Yoder (5) found that the labor reduction were 57.3% and 41.6% for stripping and packaging nonoriented and oriented leaves, respectively, as compared with the conventional tied-hand stripping system. Gooch (7) stated that burley tobacco needs to be stripped into three grades to meet the demands of domestic and export buyers.

Casada et al. (1) investigated the effects of several parameters on the force required to remove cured tobacco leaves from the stalk assuming the development of the leaf stripping machine, and found that the least force was required when the force was applied in a direction radial to the stalk.

Morrison and Yoder (4) developed an experimental tobacco stripper with counter-rotating wipers which did not have a grading system. Using their machine, a crop of stalk-cured tobacco could be stripped with at least 90% of the available leaf weight being removed for marketing.

Patterson (6) proposed a simply-constructed leaf stripping machine with three pairs of counter-rotating leaf-stripping wheels. In the use of this particular machine, the operator must move the tobacco stalk from one pair of wheels to another so as to strip all the leaves on the stalk. Thus, the leaf stripping operation still remained troublesome and inefficient.

Duncan and Tapp (2) made a study to evaluate the performance characteristics of seven different commercial leaf stripping machines. According to the results, maximum speed and maximum net tobacco value were contradictory, and the best combinations of machine productivity and net tobacco value enabled sorting into 2 or 3 grades involving two or three workers. It was also indicated that generally the stripping of one grade by hand from the lower portion of the stalk and then removing and separating the other grade or two by a machine gave the most consistent grades and best productivity per man-hour.

In Japan, only one type of leaf stripping machine was found among Japanese Utility Model Disclosures. However, this machine caused considerable leaf damage and loss, and the machine is no longer manufactured. In 1983, we investigated some
commercially available leaf stripping machines imported from the U.S.A. using domestic stalk-cut tobacco. There occurred serious leaf damage and work rates were, at best, the same as manual stripping.

Based on the previous works, the specific objective of the present research was to develop a new tobacco leaf stripping machine which satisfied the following conditions and guidelines:

1. No unstripped leaves;
2. No serious leaf damage or loss;
3. At least two times as efficient as manual stripping;
4. Sort stripped leaves into at least three grades;
5. No leaf orientating practices to be necessary following stripping, assuming direct packaging; and
6. Simple in construction, enabling low cost and easy operation.

DESCRIPTION OF THE DEVELOPED MACHINE

Fig. 1 is an isometric view of the newly developed leaf stripping machine, and Fig. 2 is a cross section of the stripping rollers which are the most important part of the machine. Fig. 3 shows how to perform the stripping operation with this particular machine. Machine specifications are given in Table 1.

Construction. The leaf stripping machine consists of a pair of leaf stripping rollers, approximately the same length as a tobacco stalk. The leaf stripping rollers lay horizontal and parallel to each other, and are in rolling contact with each other. The tobacco stalk is placed on a holding frame located above the leaf stripping rollers and in line with the rollers. The holding frame includes
Fig. 3 Operational positioning for mechanical stripping

holding rods arranged at predetermined intervals in the longitudinal direction of the leaf stripping rollers. The central portion of each holding rod is cut in such a manner as to provide a gap smaller than the diameter of the tobacco stalk. Several partitioning plates are arranged under the leaf stripping rollers as shown in Fig. 1.

Operation. As shown in Fig. 3, the operator stands on the side of the operation pedal. On depressing the pedal, the pair of leaf stripping rollers rotate in the directions indicated by the arrows in Fig. 2. The operator places a tobacco stalk on the holding rods in such a manner that the stalk is parallel to the axes of leaf stripping rollers. The base portion of the stalk is placed on a holding plate, and the tip portion of the stalk is supported by the operator with their hand. Then, the stalk is guided to the tips of holding rods and is held there, as indicated by s in Fig. 2. The stalk, s, will not drop through gap a onto leaf stripping rollers. However, the leaves touching the rollers are drawn between the leaf stripping rollers so that they are stripped from stalk s and dropped. Since a large number of ribbons are attached to each roller, the drawing of the tobacco leaves is accelerated.

There is a gap, a, between the tips of each pair of holding rods and so the holding rods do not become an obstacle to the tobacco leaves that are being drawn between the leaf stripping rollers. By rotating the stalk, s, about its own axis, all the leaves protruding radially from the stalk, s, are stripped. The desired number of partitioning plates are attached beneath the machine frame so that the leaves can be collected according to grade and the portion of the stalk from which they have been stripped. Instead of using partitioning plates, a plurality of collecting boxes, which are open on top, may be arranged under leaf stripping rollers, as indicated by the two dot and chain lines in Fig. 2.

RESULTS AND DISCUSSION

Conventional Manual Stripping. For estimation of the performance of the leaf stripping machine, it is important to understand conventional manual stripping practices in terms of work method and work rate. Thus, a survey was made in 1983 at major tobacco producing districts in Japan obtaining the results shown in Table 2. Here, the work rate was estimated as the average time needed for stripping and sorting the leaves from one tobacco plant. The number of leaves stalk-cured ranged from 8.7 to 16.0 leaves per plant indicating various types of stalk-cut harvesting, whereas whole-plant cutting is not a common practice except for some experimental trials in Japan. The stripped tobacco leaves were sorted mostly into five grades. The work rates showed significant variations among farms, ranging from 14.6 to 30.4 seconds per plant with the average rate being around 20 seconds per plant. This wide variation seems to be attributed to a variety of factors such as the number of leaves, the number of grades, and the operator's skill. As suggested in Table 2, the work rate for manual stripping slows down significantly when more than 15-16 leaves per plant are stripped. This can be explained in terms of the change of stripping practices caused by the increased number of leaves to be stripped. Namely, the operator may have

Table 1. Specifications of leaf stripping machine.

<table>
<thead>
<tr>
<th>Frame</th>
<th>Length 1,800 mm</th>
<th>Width 620 mm</th>
<th>Height 800 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>80 kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor</td>
<td>0.2 kW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stripping roller</td>
<td>Length 1,400 mm</td>
<td>Diameter 120 mm</td>
<td>Rotational speed 350 rpm</td>
</tr>
</tbody>
</table>

Table 2. Survey of manual stripping operations on actual tobacco farms.

<table>
<thead>
<tr>
<th>Farm identification</th>
<th>Variety(1)</th>
<th>Number of grades sorted</th>
<th>Work rate(2)^</th>
<th>Stalk(2) length</th>
<th>Number of leaves(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>N</td>
<td>6</td>
<td>30.0</td>
<td>948</td>
<td>9.8</td>
</tr>
<tr>
<td>b</td>
<td>N</td>
<td>5</td>
<td>23.0</td>
<td>880</td>
<td>9.9</td>
</tr>
<tr>
<td>c</td>
<td>N</td>
<td>5</td>
<td>28.3</td>
<td>990</td>
<td>8.7</td>
</tr>
<tr>
<td>d</td>
<td>N</td>
<td>5</td>
<td>19.4</td>
<td>1104</td>
<td>11.4</td>
</tr>
<tr>
<td>e</td>
<td>B</td>
<td>4</td>
<td>20.0</td>
<td>1232</td>
<td>15.3</td>
</tr>
<tr>
<td>f</td>
<td>B</td>
<td>4</td>
<td>18.1</td>
<td>1115</td>
<td>17.7</td>
</tr>
<tr>
<td>g</td>
<td>B</td>
<td>5</td>
<td>30.4</td>
<td>1307</td>
<td>16.0</td>
</tr>
<tr>
<td>h</td>
<td>B</td>
<td>5</td>
<td>14.6</td>
<td>1121</td>
<td>10.5</td>
</tr>
<tr>
<td>i</td>
<td>B</td>
<td>5</td>
<td>16.3</td>
<td>1197</td>
<td>11.8</td>
</tr>
<tr>
<td>j</td>
<td>B</td>
<td>5</td>
<td>15.0</td>
<td>1181</td>
<td>11.4</td>
</tr>
</tbody>
</table>

1) N implies native variety, and B implies Burley variety.
2) Averaged value of 30 plants for each farm.
to strip the leaves walking along a line of container boxes corresponding to several grades. In some other cases, stripping may be performed in two steps, for instance, lower half of the stalk and the rest. The examination on whole plant curing with 18.6 leaves per plant conducted at Utsunomiya Experiment Station revealed that manual stripping and sorting required as long as 44.2 seconds per plant.

**Mechanical Stripping.** In the autumn of 1987, the newly developed leaf stripping machine was tested at five tobacco farms. Table 3 shows the main characteristics of stalk-cured tobacco used in the tests. The number of leaves and stalk length varied over a wide range. The average removal force showed an appreciable variation ranging from 1.7 to 4.1 kg. Measurement of the removal force was made with a handy strain meter, determining the peak value of the force needed to remove each leaf from the stalk. The force was applied in a direction radial to the stalk grasping the base of the stem with the hook. There appeared to be a tendency for the averaged removal force to be higher with shorter stalk length. On the other hand, the pulling force generated by two counter-rotating stripping rollers was measured to be 5-7 kg. On farms No. 2 and No. 3, a few leaves were somewhat tougher. However, stripping could be achieved completely by pulling the stalk slightly toward the operator with the leaves sandwiched between the stripping rollers.

Table 4 shows the work rates of mechanical stripping under conditions where an operator was continuously engaged in stripping in conjunction with the leaf stripping machine. While the work rate was as high as 7.6 seconds per plant at farm No. 1, the average value was 11.3 seconds per plant that is 330 plants per hour. The observation through the tests revealed the high susceptibility of the work rate to factors other than the machine capacity itself. For instance, preparing the tobacco stalks on a table nearly as high as the operator’s hand and situated close to the leaf stripping machine would save a large amount of time for picking up stalks. As a whole, it can be expressed that the leaf stripping machine is approximately two times as high in work rate as manual stripping on the assumption of non-oriented stripped leaves. The work rate with the machine is independent of the number of the leaves on the stalk. This special merit leads to the high feasibility of the leaf stripping machine generating much more profit for stalk-cut tobacco cured with a higher number of leaves.

Table 5 shows the results of the examination on the degree of injury occurring to the stripped leaves. With this particular machine, all of the stripped leaves are dropped into each partition producing no leaf loss. The moisture contents are also listed in Table 5. The degree of leaf injury can not be discussed with reference to the moisture content data because there were no differences. The leaf injury appears instead to be related to the averaged removal force and other leaf properties. For example, relatively light leaf injuries were observed at farm No. 1 and farm No. 5 where the averaged removal force were relatively low. On the other hand, there occurred considerable leaf injury at farm No. 4 where the averaged removal force was relatively low but tobacco leaves were extremely thin compared with leaves on other farms. Overall, the leaf injury caused by this machine was recognized to be trivial by tobacco growers and other persons concerned.

The leaf stripping machine is simply-constructed resulting in relatively low machine cost and high durability. Since the stripping rollers are driven through a safety clutch protecting against excess load, the leaf stripping machine can be operated with high safety. The above results lead to the expectation that the leaf stripping machine could be efficiently and profitably used in Japan as well as other countries.

**LITERATURE CITED**