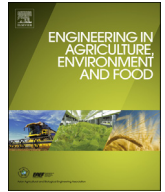




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## Development of prototype harvester for head lettuce

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### ABSTRACT

Method of manual removal of produce from the field has been a bottle-neck for lettuce production in Japan. In order to reduce the production cost of this fresh commodity, a prototype harvester has been developed for head lettuce production. The harvester consists of a cutting component to slice the lettuce head at the desired location and a lifting component that transports the harvested produce from the cutting site onto elevating conveyor and trimming station. A cutting component with reciprocating blade was proposed.

Laboratory tests were performed to verify ability of reciprocating blade to slice lettuce stump at forward cutting speed of 0.1 m/s, reciprocating stroke of 18 mm, and different reciprocating frequencies of 2, 4 and 6 Hz. In addition, power requirement for reciprocating the cutting knife as slicing two lettuce stumps was measure. Tests in lettuce fields were also conducted at different working speed to investigate the cutting and lifting performances of the harvester mounted with the reciprocating-blade cutting component. The results of laboratory tests indicated that the cutting component could smoothly cut lettuce stumps and the maximum cutting torque and cutting power requirement were 0.73 Nm and 27.7 W, respectively at 6 Hz reciprocating frequency. Field test results showed that the harvester could cut and lift the lettuce heads without damaging and blemishing the produce at working speed of 0.04 m/s and the commercial head percentage was 94.5%. At higher working speed of 0.08 m/s, the head damage rate was 12.8% reducing the percent of commercially accepted heads to 87.2%.

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### 1. Introduction

Lettuce, (*Lactuca sativa* L.), is native to the Mediterranean area and was introduced to Persian cuisine around 4500 B.C. It arrived in Japan during Heian period (794–1185 A.C.), but did not become an important commodity until the Western cuisine changed the Japanese food culture in 1980's. About 20,900 ha of the lettuce are grown year round in Japan, and 30% of which is produced during winter time in some production areas such as Nagasaki, Kumamoto, Kagawa, Shizuoka, and Ibaraki prefectures. There are approximately 791 ha of lettuce grown in Shizuoka including head and leaf lettuces. Today, Shizuoka ranks third, following Kagawa and Kumamoto prefectures, in production of winter head lettuce. The fresh produce is the prefecture's leading cash crop averaging more than 5.2 billion yen in value. Winter head lettuce is grown in paddy fields with four rows per bed cultural system using overall mulching and plastic-tunnel. The lettuce seedlings are transplanted

in a zigzag pattern with hill distance and inter row space varying from 27 to 30 cm.

While main farming practices on lettuce production such as soil preparation, transplantation, and insect pest management have been mechanized, lettuce is still harvested by hand-cut in a stopped and squatting posture using extensive labor. Furthermore, the operation is often conducted in two times due to the nonuniformity of lettuce growth within plastic film tunnels. The required working hours to produce 1 ha of lettuce is 670 h, 32% of which involves in harvesting work. Although manual labor is still preferred for fresh-market vegetable harvesting operations because of the delicate nature of the products, the need of mechanization depends upon the availability of human labor and the level of industrialization within each country. Although Japan is one the most advanced countries, its population is decreasing and aging and only 2% of the Japanese population is engaged in production agriculture now. This resulted in a severe lack of human labor for farming operations. In these circumstances, harvest work has been a bottle-neck of cost reduction and acreage expanding for lettuce production in Shizuoka prefecture.

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The incentive for mechanization of lettuce harvest depends on the available of harvesters that can achieve economies through substitution of capital for labor. Since Japanese lettuce industry is small in terms of numbers of machines and equipment that can be used, agricultural machinery companies are reluctant to invest in research and development. Therefore, research projects have been initialized by central or local governments to produce prototype lettuce harvesters which commercial firms use to adapt to commercial uses. The development concept was to replace the hand selector-cutter-trimmers with the machine. Two prototypes of once-over harvester were developed and tested for summer-clipping head lettuce grown one row per bed (Suzuki et al., 2003; IAM-BRAIN, 2003). The first prototype was developed at Agricultural Experiment Station of Nagano prefecture. The machine cut the lettuce by a rotating serrated disc and lifted it to leaf eliminating elevating conveyor at which hand trimmers removed the wrapper leaves. The trimmed lettuce then was delivered to the accumulating belt to dissipate the latex using water washing nozzles and packed in the cartons. The later prototype that was developed by IAM-BRAIN consisted of two horizontal orientating discs, followed by an oscillating circular-sector cutting blade and a tilted floating conveyor. A cutoff unit was mounted at the rear end of the machine. However, none of these experimental harvesters were commercially accepted because of high labor input requirement. The main bottleneck of these harvesters was hand trimming and latex dissipation.

Consequently, an experimental once-over lettuce harvester has been constructed and tested for four-row furrow-irrigated cultural system at Shizuoka Prefectural Research Institute of Agriculture and Forestry. The objectives of the harvester development are to mechanize the lettuce harvesting operation which will help prefectural lettuce growers to reduce production cost as well as to expand lettuce acreage by using the abandoned arable. The harvesting concept is to cut the lettuce head and lift it onto packing belt. The hand trimming and latex dissipating will be conducted at the storage facility. The experimental harvester consisted of a chassis with rubber crawler running gears, a cutting component, a lifting component, and a packing station. The output product of this harvester is undamaged and unblemished heads with straight stump cut and 2 to 6 wrapper leaves, and the rate commercialized heads over harvested heads is more than 95%. In this paper, the development of a cutting component with a reciprocating blade and a lifting component is mainly described and results of laboratory and field tests are also reported to evaluate their performance.

## 2. Materials and methods

### 2.1. Conventional practice of lettuce harvest

Japanese winter lettuce transplantation starts at the end of September and continues to the beginning of February. Harvesting

takes place primarily from November through April. When temperatures cool down, lettuce rows are covered using plastic film tunnels to minimize the depressed effect of cold weather on the plant growth. However, this farming practice has involved much in the growth difference between the inner and outer rows of lettuce due to the nonhomogeneity of the temperature distribution inside the film tunnels. Once-over harvest of lettuce head is applied before January (Fig. 1a) and after that selective harvest is conducted by cutting two inner rows first (Fig. 1b and c). It takes about a week to do the second harvest of the outer rows. After the lettuces are selected and cut using a sharp cutting implement such as a knife, they are trimmed with a certain number of wrapper leaves left.

Lettuce in Shizuoka is shipped using two packing techniques: naked pack or film wrap. Field packaged and shipped lettuce is cut at about the middle leaf, and trimmed to leave three wrapper leaves, then packed in the carton or plastic containers. Each container contains two layers of 12–18 heads depending on the head size. The top layer packed stump-up is washed to dissipate latex sap which excluded from the stump cut before shipping. For film-wrapped lettuce, heads are cut under the last basal leaf, trimmed to remain three to five wrapper leaves, then packed in containers and transported to storage facilities. The produces are then trimmed again to remain one wrapper leaf, dissipated the latex sap and wrapped with cellophane at the facilities before shipping. After harvest, the beds with plastic mulch will be used for further planting of sweet corn or even for the second transplantation of lettuce.

### 2.2. Design concept of the experimental harvester

Generally, manually harvested lettuce is a mature, undamaged and unblemished head having the stump cut straight across to remain a desire number of wrapper leaves. Because winter head lettuce in Japan is grown inside plastic film tunnels, selective mechanical lettuce harvest is technically unfeasible. Some practices such as utilizing starter dressing or green house culture have been studied at the Shizuoka Prefectural Research Institute of Agriculture and Forestry to improve the growth uniformity of winter lettuce that can minimize the harvest lost due to immature heads if once-over harvest is applied. Consequently, the experimental lettuce harvester must meet the following requirements:

- to mechanize once-over harvest of multi-row winter lettuce with efficiency four times higher than hand cut;
- to injure and blemish the heads as less as possible;
- not to damage the mulch;
- to improve the working posture of workers;
- for naked pack technique, lettuce heads will be trimmed to remove unwanted wrapper leaves, packed and dissipated the latex sap at the packing station;



Fig. 1. Conventional harvesting practices of head lettuce in Shizuoka prefecture.

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