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Design and Manufacture of Prototype Leek Harvesting Machine

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Abstract: In our country, leek plants are harvested by hand. Labor costs are very high in leek harvesting like harvesting the other vegetables. In this study, mechanization possibilities of leek harvesting were investigated. The first step of the leek harvesting is pulling the leek up by hand. Therefore, a rooter part must be equipped to the leek harvesting machine. In this study, "Prototype Leek Harvesting Machine" was designed and constructed.
Key words: Leek harvesting, leek, vegetable, mechanization, prototype machine

INTRODUCTION

Because of the proper ecological conditions of Turkey that has an important agricultural production possibility, the vegetable production is performed on 3% of the total 23.8 million ha of cultivated area while the field crop cultivation, fruit growing, olive production, viniculture and vegetable production are also done on 87.3%, 5.4%, 2.3%, %2 and %3 (806 000 ha) of the total cultivation areas, respectively. In recent years, 35 million tons of fresh vegetables are grown. Fresh vegetable production keeps the 24.6% of the total agricultural production. Leek production value of our country is 310 000 tons in average. (TÜİK, 2007).

Except some developed European countries, machines are not used for vegetable harvesting. Although the agricultural production practices are mechanized at many crops that have industrial importance, machines are not used in harvesting of most of the vegetables because of insufficient research.

In our country, leeks are completely harvested by man power. The leek harvest is quite difficult and laborious. In harvest of the leek, the processes are summarized as pulling the plant up from soil, peeling the outer leaves, carrying them to bunching place, bunching the plants and loading (Uğurluay, 2008). Among these processes, the most important and laborious one is the pulling the plant up from soil (Figure 1).

Figure 1. Pulling process in leek harvest.

Labor cost that spends for harvest is approximately 70% of total cost in a farm which is done leek production in Çukurova. Among harvesting processes, the rate of pulling is about 15% (Uğurluay, 2008).

If a machine is used at leek harvest, the labor costs can be decreased and the other processes in harvest like peeling, carrying, bunching, loading can be done in appropriate conditions.

Because the pulling is the first step, it considerably needs more power and the most tedious process, it is primarily studied for the solution of this problem. Therefore, a prototype leek harvesting machine is designed and constructed. The machine is only for pulling the plant from the soil.

The aims of the study were as follows:

- To provide a chance for machine usage in leek harvest that is completely depend on labor and manpower.
- To increase operation capacity in the production.
- To decrease the harvest costs.
- To decrease the harvest loss.
- The harvest is done in hard field conditions in winter season. To implement the first step of the harvesting processes which is pulling the leeks by machinery in the field. To supply the proper conditions for the other post harvesting processes in a closed facility.
- To support development of this kind of harvest machines.

MATERIAL and METHOD

Measurement of pulling force of leek plant is a very important data for the purposes of mechanization. Since leeks are harvested with their roots for plant properties and the market demands, an apparatus which can pull the plant was used. The apparatus was simply composed of two covers, hinge and bolt-nut system.

The covers were properly sized and shaped considering the average diameter of plants. A rubber material was also stuck on inside of the covers to supply better friction between leek stalk and covers. Pulling apparatus is shown in Figure 2.

The important data that will be used for designing the pulling system is to determine the static and dynamic friction coefficients which occur between pulling bands and leek plants. It is suitable using the static friction coefficient in computations by reason of full contacts between pulling bands and leek plants (Uğurluay, 2008).

$$\mu = \frac{Fs}{N} \qquad (1)$$

Here,
μ : Friction coefficient (-),
Fs: Friction force (N) and
N: Normal force (N).

Some basic dimensions and parameters of the machine were determined by using the all harvest information and the physical properties of leek plants. Dimensions of the machine's frame were sized by considering plantation condition of the leek plant in field. Some dimensions of the plants in field were shown in Figure 3.

First of all, draft drawings were done. After making some revisions, then, detailed drawings of manufacture were drawn. The prototype machine was constructed, after deciding upon materials and manufacturing processes.

Figure 2. The apparatus which was used for measurement of pulling force of leeks and pulled plant.

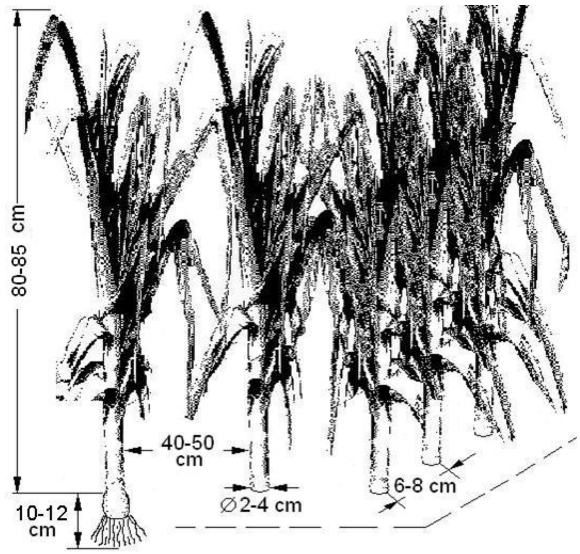


Figure 3. Some dimensions which were benefited in design.

RESEARCH RESULTS

Long fibrous roots of the plants make hard the pulling process. For this reason, some plants are separated from their body when manual harvesting. Such a crop doesn't have any market value and it will be wasted. Pulling force values of leek plants were shown in Table 1. In Table 2, some values are given for the plants that are broken during the pulling processes.

Table 1. Leek Plants Pulling Force (Uğurluay, 2008)

Feature	Value
Average Force (N)	338,5 ± 105,7*
Average Plant Dia. (mm)	25,55 ± 4,6*
Average Soil Moisture (%)	21,8 ± 0,60*

*Standard deviation

Table 2. Leek Plants Breaking Force and Diameters (Uğurluay, 2008)

Feature	Value
Average Force (N)	278,0 ± 88,9*
Average Plant Dia. (mm)	23,85 ± 2,33*
Breaking Dia. (mm)	20,99 ± 4,95*
Average Soil Moisture (%)	21,8 ± 0,60*

- Standard deviation

The values in Table 1 and the experiences from the field experiments showed that there is a need for loosen the soil around the root for using the machinery during pulling.

The following constraints were taken into account for designing the machine which will work on pulling based on the results of the experiments and examinations.

- The leek plant is marketed with its root. Thus, it is necessary to pull the plant with its roots.
- The plant is planted in rows and it must be pulled from the row.
- A blade must be used for cutting the plant roots and loosen the soil because of the high pulling forces.
- Because the plants are planted closely, the pulling process must be done continuously. The movement of the machine and pulling operation will be done simultaneously without stopping.

If the criteria above were taken into account, the basic organs of the prototype machine are form of a pair of leader, a blade, a pair of pulling band-pulley mechanism and suppression pulleys (Figure 4).

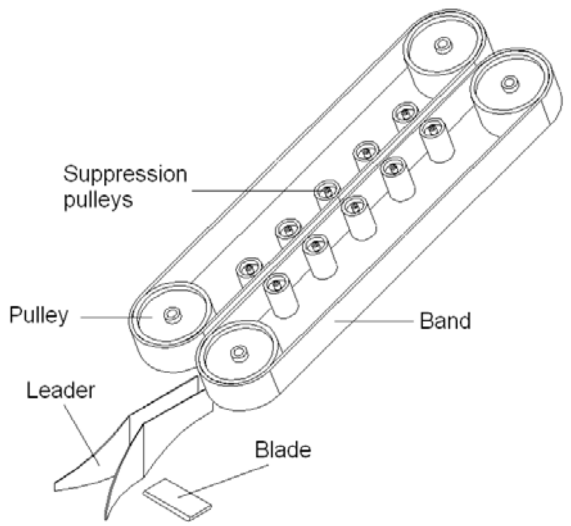


Figure 4. The basic components which are on the prototype leek harvesting machine.

The plant will first come into contact with the leaders. The leaders supply the plant body to stand up, grabbing to the plant body by the pulleys and guiding the stalks to interspaces of the pulleys. Just before taken the plant by the pulleys, the root connection of the plant will be cut by a blade.

The plant which cut under the root region will be grabbed by a pair of pulleys that turn opposite directions. The plant will be lifted up and taken back in a certain angle.

The angular velocities are "ω_1" and "ω_2" in grabbing process by drums which have flat surfaces, different velocities and can turn in opposite directions (Figure 5).

The diameters of the drums and the distance between them can be shown as "D_1", "D_2", and "a", respectively. Assume that the vertical forces affected on the stalk that has the thickness "h" are "N_1" and "N_2" and the friction forces that affect the drums as tangent are "F_1" and "F_2" (Klenin, 1986).

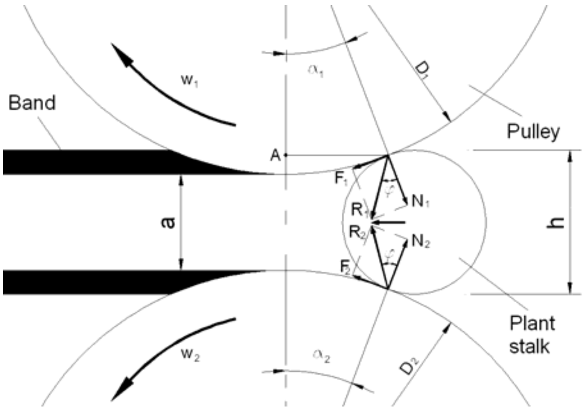


Figure 5. The diagram which determines grabbing conditions of the plant stalks by the drums which have flat surface.

The equation for drums to grab the plants can be expressed as follows by writing the forces with the working direction:

$$F_1.\cos\alpha_1 + F_2.\cos\alpha_2 \geq N_1.\sin\alpha_1 + N_2.\sin\alpha_2 \quad (2)$$

$$F_1 = N_1.\tan\varphi_1 \quad \text{and} \quad F_2 = N_2.\tan\varphi_2 \quad (3)$$

φ_1 and φ_2 are friction angles. When we replace them in equation 3, the following equation can be obtained;

$$N_1.\tan\varphi_1.\cos\alpha_1+N_2.\tan\varphi_2.\cos\alpha_2\geq N_1.\sin\alpha_1+N_2.\sin\alpha_2 \quad (4)$$

In manufacturing, drums with equal diameters are used. For this reason, the following assumptions can be used.

$$N_1 = N_2, \qquad \alpha_1 = \alpha_2 = \alpha$$

If the expression was re-written according to the assumptions, the condition which is necessary for drums to grab the stalks is:

$$\tan\varphi_1+\tan\varphi_2 \geq 2.\tan\alpha \quad (5)$$

There must be enough number of suppression pulleys for preventing the stalks to fall. Static friction coefficient "μ_s" which is between leek stalk and band is 0,576.

Dynamic friction coefficient "μ_d" is 0,485 (Uğurluay, 2008). The angle "α" was measured as 21º by using real dimensions (Figure 5). In this case;

$$\mu_s = 0{,}576 = \tan^{-1}\varphi \qquad \varphi = 29^\circ$$

$$\tan 29 + \tan 29 \geq 2.\tan 21$$

$$1{,}1 \geq 0{,}76$$

As a result, plant stalk can be grabbed by the pulleys by using the designed sizes.

The plant which is between the bands must be carried from the soil to up in a certain angle on the horizontal axis. The velocities which come up in such a pulling machine with band and pulley mechanism are "Vm" and "Vb" (Figure 6).

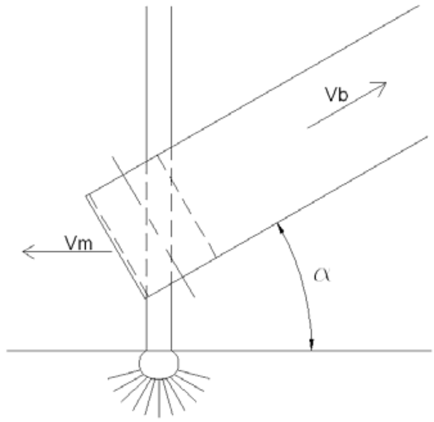


Figure 6. The velocities which affect a leek plant that was gotten in space of the band.

The velocity diagram shown in Figure 7 was drawn to better understand the effect of forward velocity of the machine and band velocity on leek plant. Movements and velocities are developed on a certain plane. Machine velocity occurs on the direction of –x and the direction of the band velocity is on a certain angle with +x.

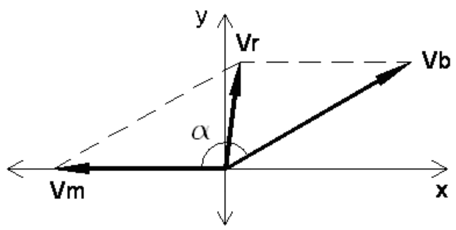


Figure 7. The relation between machine forward velocity and band velocity.

The plant which is moved by resultant of these two velocities (Vr) was forced upright near to the axis +y. The band forward velocity was chosen higher (25%) than the machine forward velocity. Machine forward velocity was chosen as 5 km/h (1.38 m/s). Consequently, the band velocity will be 6,25 km/h (1,73 m/s). The pulling up velocity of the leek plant is;

$Vr = \sqrt{(Vm^2 + Vb^2 + 2.Vm.Vb.Cos\alpha} =$ 3,15 km/h (0,88 m/s).

It is necessary to compress the bands to each other with a certain force to prevent the plants to fall. To achieve this process many suppression pulleys were used by placing them facing one another. The static friction coefficient between plant and band was used to find the suppression forces of springs.

The following forces that affected on a plant between two bands are: "G" is total weight (plant and some soil in the root), "Fs" is friction force, and "Fsp" is spring suppression force (Figure 8).

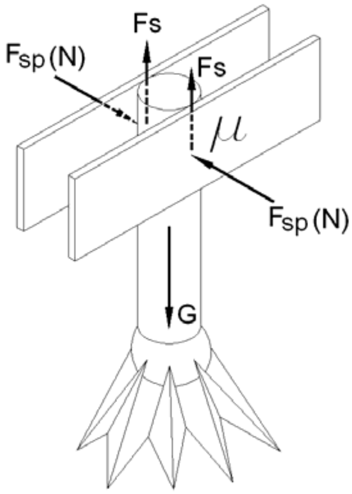


Figure 8. The forces on the leek stalk that is between on bans.

Following equation was used to calculate the suppression springs forces.

$$N = \frac{Fs}{\mu} \qquad N \geq G$$

The gravity of a plant with some soil approximately weights 20 N.

$$N = \frac{Fs}{\mu} \qquad Fs \cong G$$

$$N = \frac{G}{\mu} = \frac{20}{0{,}576} = 34{,}7N$$

The suitable forward speed of tractor is assumed to be 3-5 km/h for leek harvest. The backward speed of bands were planned to be 25-50 % higher than the tractor forward speed at the time of pulling and picking. The number of revolutions of pulleys was obtained from the calculations by substitution of these speeds. By using the revolution number, the pulleys diameters and teeth numbers of sprockets were calculated. The band speed is also the tangential velocity of the pulley. At the forward speed of tractor, the band speed is;

Vb = 1,38 . 1,25 = 1,725 m/s

Vb = 1,38 . 1,5 = 2,70 m/s

Choosing the band speed as between 1,725 – 2,70 will be suitable. The most accurate value will be obtained from the field tests.

The number of revolutions of pulley which has a diameter of 0,23 m is;

$$V_t = \frac{\pi.D.n}{60}$$

Here;

V_t : Tangential velocity of pulley (m/s)

D : The diameter of pulley (m)

n : The number of revolutions of pulley (min-1)

$$n = \frac{V_t.60}{\pi.D} = \frac{1{,}725.60}{\pi.0{,}23} = 143{,}2 \text{ min}^{-1}$$

The number of revolutions of pulley can be between 130 – 160 min^{-1}.

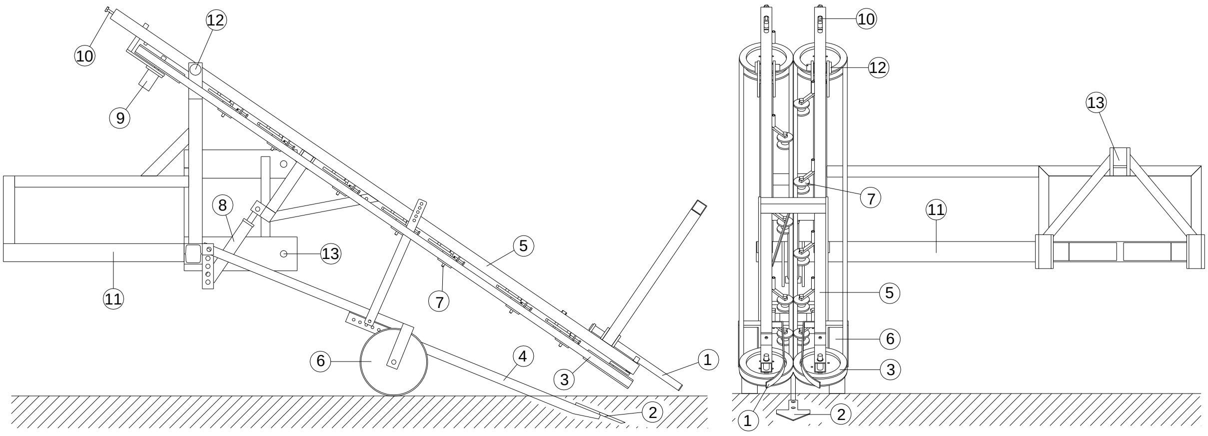
Prototype Machine

This study was sponsored by T.C. Department of Trade and Industry and a firm (Öz-İş İmamoğlu Tarım Makineleri) in partnership as a SANTEZ Project.

Firstly, the location of the machine on a tractor was considered and for this purpose it was agreed that the three point linkage was the most appropriate linkage. Besides, it was decided that the prototype machine is going to work at the right side of tractor and harvest the plants on a single row.

Left side and front views of the prototype machine in working conditions are given in Figure 9.

Isometric view of the prototype machine is shown in Figure 10.



1	Leader	8	Hydraulic cylinder
2	Blade	9	Hydraulic motors
3	Pulling and carrying bands and pulleys	10	Band tensing device
4	Blade arm	11	Basic frame
5	Picking unit frame	12	Joint
6	Depth wheels	13	Three point linkage
7	Suppression pulleys		

Figure 9. Left side and front views of the prototype leek pulling machine (In working conditions).

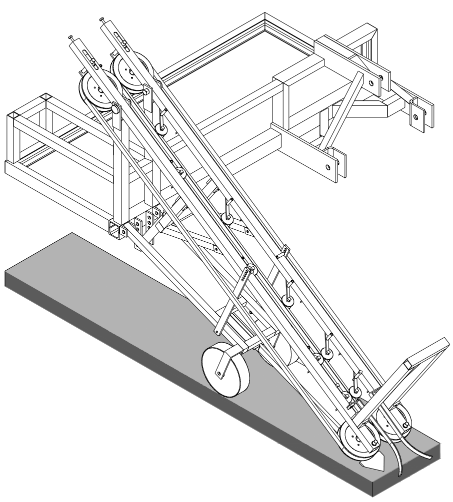


Figure 10. Isometric view of the prototype machine.

DISCUSSION and CONCLUSIONS

The leek harvesting machine was designed as a simple machine. So, it was aimed that the machine can be manufactured easily with a low cost and can be bought by leek producers.

The number of studies on this subject is very few in our country. With the success of the project, the first steps of the development of vegetable harvesting machines will come true. This machine and latter improvement efforts can be evaluated as studies that have high potential of patent and beneficial model.

The usage of a machine in leek harvest will be the first step on the way mechanization in vegetable harvest. And it can form a vision in designing new vegetable harvesting machines. This process will bring innovation to the sector of agricultural machinery.

By using new harvesting machines, the labor costs will be decreased, and these will affect the market prices.

Like problems in harvesting the industrial field crops, there will be some problems in finding the labor for harvesting the vegetables. For this reason, mechanization in vegetable production must be evaluated as an important and strategic development.

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