Development of a Harvest Mechanism for the Kahramanmaraş Chili Pepper

O. E. Akay, E. Güzel, M. T. Özcan

***Abstract*—**The pepper has quite a rich variety. The development of a single harvesting machine for all kinds of peppers is a difficult research topic. By development of harvesting mechanisms, we could be able to facilitate the pepper harvesting problems. In this study, an experimental harvesting machine was designed for chili pepper. Four-bar mechanism was used for the design of the prototype harvesting machine. At the result of harvest trials, 80% of peppers were harvested and 8% foreign materials were collected. These results have provided some tips on how to apply to large-scale pepper Four-bar mechanism of the harvest machine.

***Keywords*—**Kinematic simulation, four bar linkage, harvest mechanization, pepper harvest.

I. Introduction

FIRST experimental pepper harvest machines had been developed in 1968. Recently 230 machines have been made for 20 different types of pepper. 30 different types of harvesting mechanisms had been made and tested on worldwide. The different picking mechanisms were worked well, depending on crop conditions and machine adjustments. Some harvesting machines have been designed by withdraw types and moveable types [1]. Many different harvest mechanisms have been tested. spring tines [2], [3], rigid or flexible rakes [4], [5], forced balanced shakers [6], open-helix picking bars [7], [8], cylindrical brushes [9] are some of these. Although many working is made for harvest mechanisms, number of commercially produced harvest machine is little.

The current commercial pepper harvesting machines are collecting large amounts of foreign material with the product. The necessary additional mechanism to separate the foreign materials increases machine sizes, energy consumption. The other problem is the falling down crop on the ground during harvest. Most harvest machines had given acceptable results depending on plant, the crop features and machine adjustment. Harvested crop had been between 70% and 90% [1], [4].

II. Materials and Methods

Harvest trials were made in the pepper fields in the Kahramanmaras Agricultural Research Institute in mid-October (Fig. 1). During the harvesting experiments, the distance between plants was 30 cm and row spacing was arranged as 80 cm.

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Fig. 1 Chili pepper field at Kahramanmaras Agricultural Research Institute

A manually actuated experimental harvesting mechanism was used in harvest experiments (Fig. 2). Mechanism is designed with steel-tines, which moving at the vertical direction. The diameter and length of the tines were chosen as 2 mm and 300 mm. Space between tines were arranged as 15, 20 and 25 mm. Strength, elastic shape changing ability, low cross-section area have been basic factors for selection of tine material.

Fig. 2 Manually actuated experimental harvest mechanism

A digital force gauge has been connected to be able to measure forces on the mechanism (Fig. 3). Diameter of steel-tines are 2 mm, length of them are 300 mm. Intervals between of the Steel-tines are arranged 15-20-25 mm. Steel-tines are formed from spring-steel material.

At the design studies, two software were used for kinematic simulations [10], [11]. One of them was written with Visual Basic 6.0 version for the analysis of the harvesting mechanism trajectory. This software simulates the motion of harvesting mechanism and gives the graph of trajectory. A working screen sample of this software was given at Fig. 4. This software offers the option to split-screen simulation. Dimensions and angles are entering to the working screen for constituting mechanism.

Other software named "Working Model 2D 8.0.1.0" was used for kinematic analysis of the harvesting mechanism. (Fig. 5). This mechanism consisted of stripping steel-tins. Four bar linkage mechanism was arranged reciprocal.

Prototype pepper harvest machine was developed as a result of works with experimental harvesting mechanism experiments and simulation softwares. In Fig. 6, the working principles of a prototype machine are shown. Movement of harvesting mechanism, obtains from a hydraulic power unit with 22.5 l/min in capacity which is driven from hydraulic circuit of tractor.

Prototype of pepper harvest machine used in the field experiment is shown in position connected to the tractor in Fig. 7. The hydraulically-powered, single row prototype was mounted on the three-point hitch of tractor. Harvest mechanism was designed to give less damage to the plant for the second harvest.

Fig. 3 Force measurements with experimental harvest mechanism

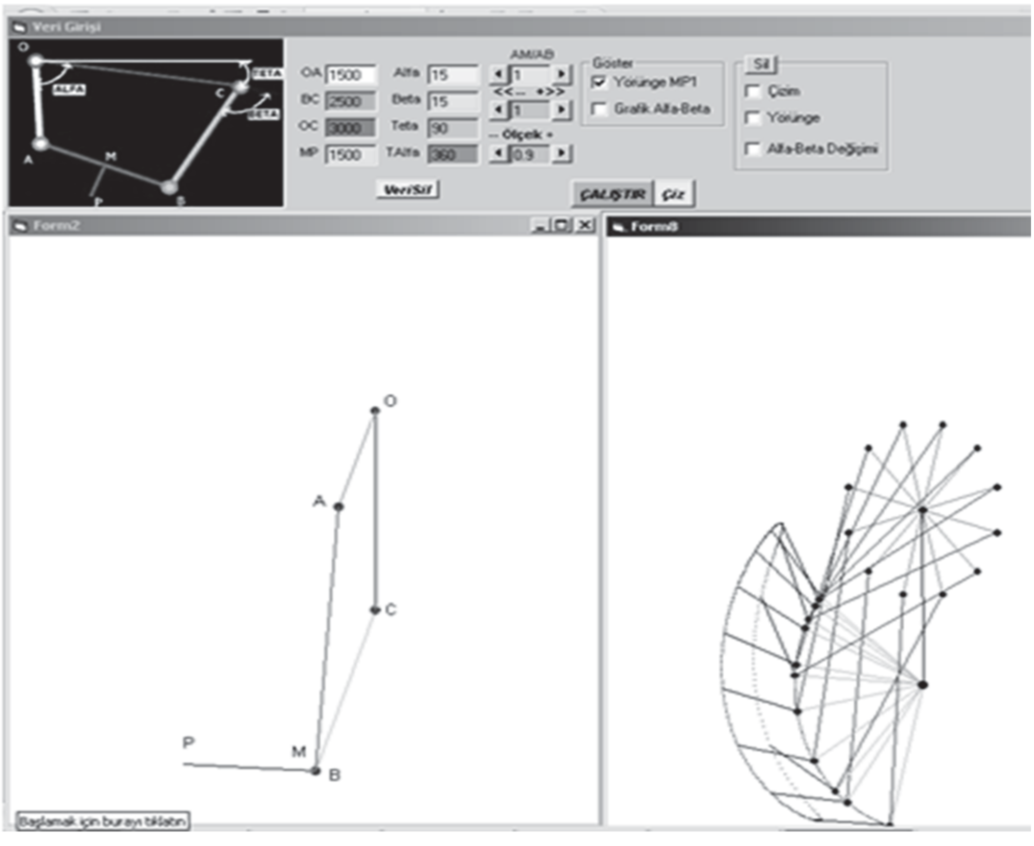

Fig. 4 Four bar linkage trajectory simulation software

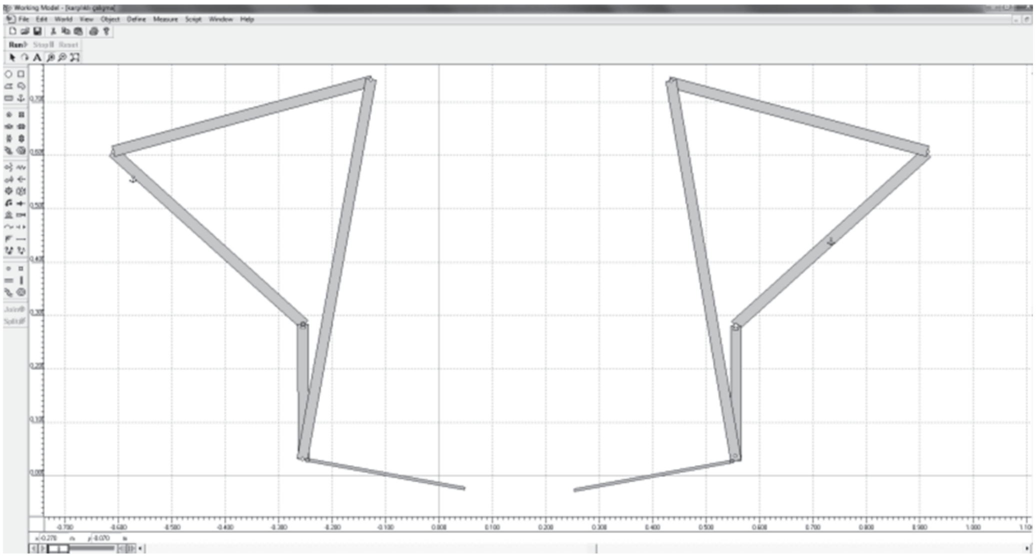

Fig. 5 Working Model 2D simulation screen

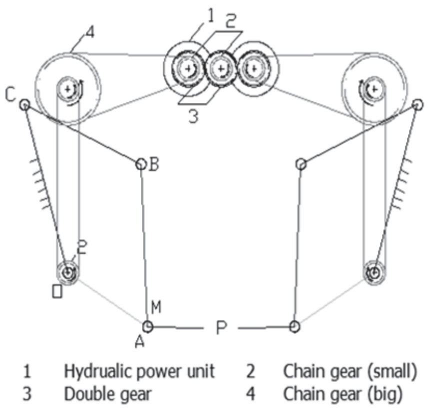

Fig. 6 Working principle scheme of the pepper harvest mechanism

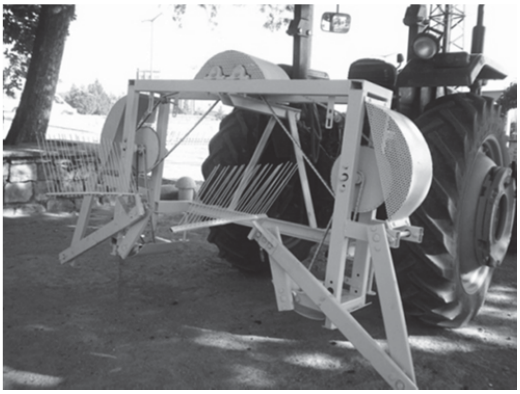

Fig. 7 Prototype Harvest machine

III. Results and Discussion

The body of pepper plant is having a highly branched structure. The shape of the plant branches makes difficult of the harvesting mechanism movement. To reduce this problem, the manually-actuated picking mechanism has been designed with steel-tines. While tines are moving through the pepper plant from bottom to top, peppers are removed from abscission layer (Fig 8). This feature is a very important factor which facilitates for the mechanical harvest of the pepper [12]. Harvest trials have been made on four plant, over 30 fruits to determine the required force to remove pepper from the plant using manually actuated picking mechanism. Forces have been measured at different values between 5 and 42 N with a mean of 22 N. These results have been presented on Table I.

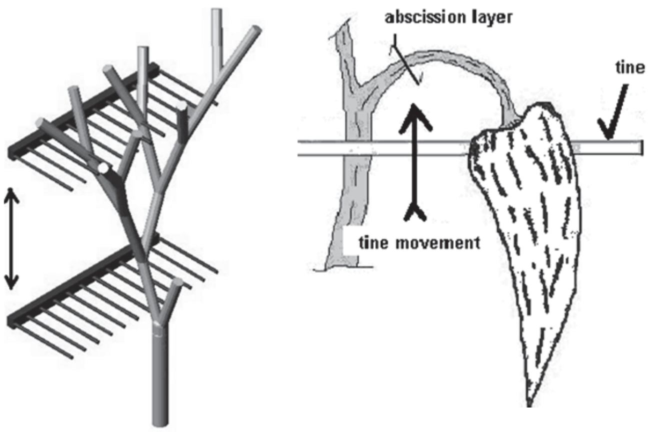

Fig. 8 Principle of pepper removal by tine

Pre-harvest experiments were performed with three different manually-actuated picking mechanism type. Tin interval was arranged as 15, 20 and 25 mm. When 15 mm tin interval is used, the plant body is highly damaged. At the 25 mm tine interval, tines have moved easily inside the plant, and %30 of the fruits was collected. 20 mm tine interval gave the best harvest result, 80% of the fruit were collected and didn't damage to the plant significantly. Different tine intervals have given different results and also impacted harvest success. These results have been presented on Table II.

TABLE I
FORCE REQUIRED TO REMOVE FRUIT FROM THE PLANT EXPERIMENT RESULTS

No	Force (N)	No	Force (N)	No	Force (N)
1	9	11	28	21	38
2	12	12	33	22	36
3	21	13	42	23	28
4	24	14	26	24	23
5	30	15	26	25	12
6	32	16	14	26	18
7	18	17	17	27	34
8	5	18	8	28	9
9	19	19	23	29	24
10	22	20	22	30	21

TABLE II
PROPERTIES OF TINE MATERIAL AND RESULTS

Properties of tine material	Results
Insufficient strength	Bending of tines, easy moving ability of steel-tins
Rigid material	Jamming on plant body, high level plant damage and foreign material
Big cross-section	High strength and rigid structure, high level plant damage and foreign material
Small cross-section	Insufficient strength, less rigidity, easy moving ability of steel-tins
Narrow tine space	Jamming on plant body, high level plant damage and foreign material, increase of harvested crop
Wide tine space	Easy moving ability of steel-tins, lower harvest success

Theoretically, four-bar mechanism can produce an infinite number of trajectories. Therefore, four-bar mechanism has been selected as the main mechanism. Mechanism sizes were determined according to external dimensions of the pepper plant (Fig. 9). For harvesting the peppers, four-bar mechanism was designed reciprocal. In this mechanism, tine (AP) was fixed to AB coupler.

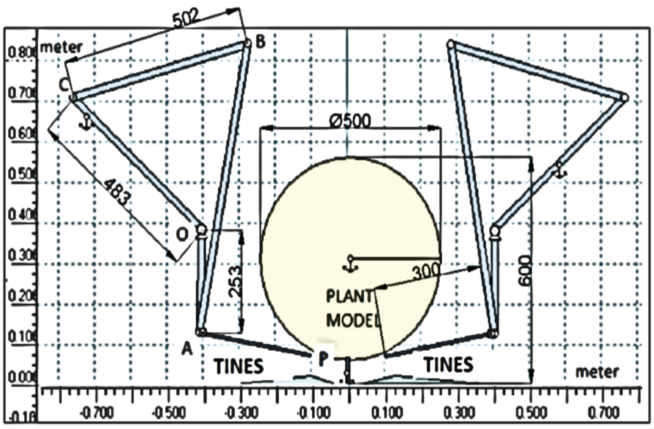

Fig. 9 The plant body model and four-bar mechanism

Trajectory of harvesting mechanism was determined with the aid of simulation softwares (Fig. 10). Trajectory is the end point of the tin.

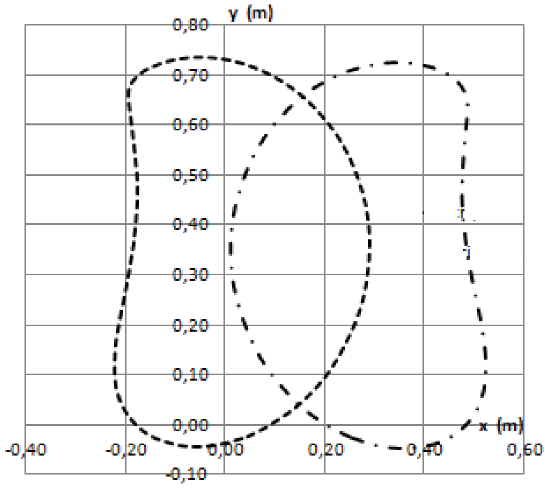

Fig. 10 Movement trajectory of stripper-comb

When the prototype pepper harvest machine was planned, the following factors have been considered for tins. It is important to give less damage to plant and fruit during this motion, thus foreign material is collected quite less. Speed of return motion must be higher from plant harvest speed. The harvesting experiments were made by prototype machine over the same three rows with 50 m length (Fig. 11). Experiments have given different results for the harvested fruit and foreign material. This differences were found statistically important ($p<0.05$).

Fig. 11 Harvest experiments with prototype pepper harvest machine

Each experiment was repeated three times; harvest results are presented in Table III. When the tractor speed was 0.36 m/s and OA link turning speed was 60 rpm in trial experiment, the best results were obtained. 72% fruit on the plants have been removed in the harvesting experiments. When OA linkage speed 30 rpm, harvest success was low. Because of the low rotation speed, plant escaped from among the tines easily.

The trajectory of the steel-tines depends on the mechanism speed and tractor speed. (Fig. 12). The increasing speed of the tractor increases the angle of tilt in the direction of progress of the pepper plant. It is necessary that increase the speed of tine, to compensate for this. If speed of stripper-comb increases, higher resisting forces may occur inside the plant and the damage may increase inside the plant.

TABLE III
HARVEST RESULTS

OA link rotation speed (rpm)	Tractor speed (m/s)	Harvested crop (%)	Foreign matter of harvested crop (%)
30 (n1)	0.36(V1)	68 (d)	7 (d)
	0.47(V2)	61 (f)	8 (d)
Average		65 (C)	8 (C)
60 (n2)	0.36(V1)	72 (c)	8 (d)
	0.47(V2)	64 (e)	12 (c)
Average		68 (B)	10 (B)
90 (n3)	0.36(V1)	81(a)	14 (b)
	0.47(V2)	76(b)	18 (a)
Average		79 A	16 A
	V1 Avr.	74 (A)	10 (B)
	V2 Avr.	67 (B)	13 (A)

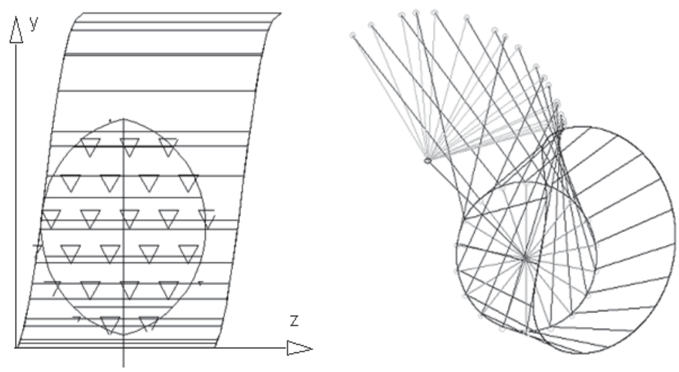

Fig. 12 Position changing of tine end point (P) (OA link rotation speed 60 rpm, tractor speed 0.36 m/s)

IV. CONCLUSIONS

Steel-tines moving in the plant is designed for least possible jamming. Abscission layer in the stem of the pepper fruit is the main factor which making easier to harvest. In this way, the fruit of the plant can be separated from the branch by a low force. High plant density, high plant structure, small branch angle make a positive impact on machine harvest efficiency. However, higher plant densities increase the rate of foreign material in the harvested peppers. The required force to separate the fruit of pepper from the plant depends on the genetic characteristics of pepper varieties. Therefore; pepper varieties having less tensile strength is advantageous for machine-harvest.

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