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Harvesting of Kahramanmaraş Red Pepper by a Trajectory Based Prototype Machine

O. E. AKAY[1], M.T. ÖZCAN[2]
[1]Technical Departments, Kahramanmaraş Technical Vocational School of Higher Education,
Kahramanmaraş Sütçü İmam University 46001 Karacasu-Kahramanmaraş, Turkey
akayorhan@msn.com
[2]Department of Agricultural Machinery , Faculty of Agriculture, Cukurova University
01330 Balcalı-Adana, Turkey
mtozcan@cukurova.edu.tr

Abstract: In this study; a prototype harvest machine have been made for the Kahramanmaraş red chilli pepper. Interaction between stripper harvest mechanism and plant was examined. Motion orbit of mechanism was detected by specially prepared simulation software. Designed mechanism is a four bar linkage mechanism. Its orbit was developed to be able to be harvested in accordance with the features of the plant. A special orbit mechanism which was operated with a suitable movement according to the picking direction of pepper harvests the plant by the strippers of a comb from down to up. In generally,it was seen that harvest success of different maturity degrees of plant effected different physical dimensions of the fruits of pepper plants importantly. In design, but the percentage of high harvest also the percentage of low foreign material. was based. Field tests had been made in diffrent machine and mechanism speeds by prototip machine. In field experiments when percentage 81 of the peppers were harvested undesirable plant materials (stem, and undesireable fruit from machine-picked.) was percentage 14.
Key words: K.Maraş Red Chilli pepper, mechanically harvest, four-bar linkage, kinematic simulation.

INTRODUCTION

The pepper has quite a rich variety and physical and bio-technic properties. These properties are quite effective on obtaining results by mechanical harvesting and accomplishing only one machice which will be harvested for all pepper varieties is very difficult (Salton and Wilson, 2003; Marshall, 1984b). First experimental pepper harvest machines had been developed in 1970. Recently 230 machines have been made for 20 different types of pepper and 30 different types of harvesting mechanism had been made and tested on worldwide. Some harvesting machines has been designed withdraw type and some are moveable types (Marshall and Bose, 1998). Harvesting mechanisms consist of rigid or flexible tines placed on a rotating band (Salton and Wilson, 2001; Gentry and *et al.*, 1978)

Harvest mechanism consist of different designs, such as rigid or flexible rakes (Salton and Wilson, 2001; Gentry ve *et al.*, 1978) helix mechanisms, cutters (Lenker and Nascimento, 1982), bilateral arrenged cylindrical brushes (Palau and Torregrosa, 1997).

Plant pattern, pyhsical structures of fruits and bio-technical features have a significiant impact on machine harvest efficiency. Therefore high plant density, high plant structure, small branch angles make a positive impact on machine harvest efficiency. However, high plant density, causes the amount of foreign material it is significant increase. This case makes the process to distinguish crop from the foreign plant material diffucult (Lenker and Nascimento, 1982; Marshall, 1984a, 1984b).

Until the present harvest machines which had been manufactured, would collected foreign plant material quite important quantity. One of the important problems is that the crop seperates from these materials. One other problem is the lost crop falling down while is being harvested. Most of the harvest machine had given acceptable results depending on plant, the product features and machine adjustment and percent of harvested crop had been between %70 and% 90 (Marshall and

Boese, 1998; Lenker and Nascimento, 1982; Palau and Torregrosa, 1997, Wolf ve Alper, 1984).

Although a lot of work made on harvest mechanism of pepper plants today from the past, commercially produced harvest machine is little. While these machines harvesting pepper, at the same time they collect a large amount of foreign plant material. Machine sizes, energy consumption and production costs are high because of the necessary additional mechanism to separate and transmit these unwanted materials.

In this study, the prototype machine had been made for harvest K.Maraş red chilli pepper. Harvest elements of this machine had been constituted stripper combs which consists of arrangement of adjacently tines. Field testing has been materialized different machine and in harvest mechanism speeds by prototype machine.

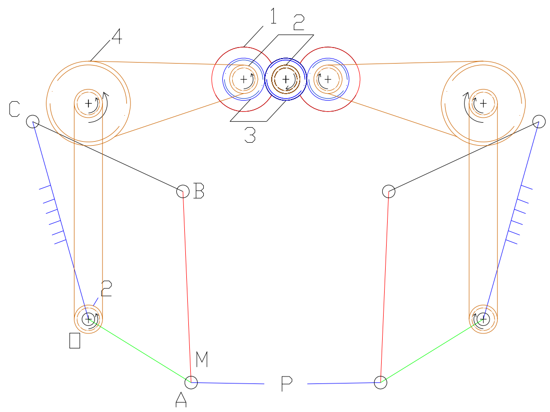
MATERIAL AND METHOD

Material

Trials had been made in K.Maraş Agricultural Research Instute. Distance between rows are 0.8 m. Plants are spaced 0.3 m on rows. At the begining of harvest the prototype, harvest machine used in field experiments is designed as a stripper harvest mechanism executed pulling up by hand on a vertical line (Figure 1.). A digital force gauge (max. 200N) has been connected to be able to measure forces on the mechanism. Diameter of stripper tines are 2 mm, lenght of them are 300 mm and material is spring steel. Spring tines are spaced 15, 20 and 25 mm adjacently.

Figure 1. Experimental harvest mechanism

A prototype pepper harvest machine for use in the field trial results was developed as a result of work by a experimental harvest mechanism and simulation software. In Figure 2. the working principles of a prototype machine are shown. This machine has been consisted of stripper combs connected to arrenged four bar linkage mechanism reciprocal. Stripping comb is fixed to A point. Each of working combs mutually has been used spring steels in 30 circular forms symetrically.



1	Hydraulic power unit	2	Chain gear (small)
3	Double gear	4	Chain gear (big)

Figure 2. Working principles of the pepper harvest mechanism

Action of harvesting mechanism obtains from a hydraulic power unit with 22.5 l/min in capacity which is driven from hydraulic circuit of tractor. Hydraulic power unit gives action to the placed four-bar mechanism mutually with the help of gear and chains. In this mechanism, OC link is constant, BC link is rocker and OA link is crank.

A prototype of pepper harvest machine used in the field experiment is shown in position connected to the tractor in Figure 3. Can be seen from Figure 3., harvesting machine has been mounted to the tractor with three point system. There are two hydraulic hoses ; one connects to output of tractor hydraulic system, other connects input of it. To run the hydraulic power unit of machine used tractor must have double action hydraulic system.

Figure 3. Pepper harvest machine

Method

The edge of a digital force gauge has been connected to half open mouth ring to determine the deattacment forces. This ring was attached to handle and fruits were taken at an percendicular angle connect the nodes.

The number of collected fruit was divided to the number of harvested fruit to determine the percentage of the harvesting crop in testing with a stripper comb mechanism and a prototype harvesting pepper machine. Foreign material weight in the harvested material (leaves, branches, etc.) has been compared to the product weight to find the percentage of non-material products. Basic factors were taken into consideration such as strenght, elastic shape changing ability,l ow cross-section area in the direction of movement, not to cut ripping the plant from the root in the plant or not to compress significant damage to being selected materials of stripper elements creating comb and the form.

Kinematic simulation software was written by Visual Basic 6.0. This software is either simulates the harvesting mechanism and draws the stripper comb orbit (Figure 4.). Working model 8.0.1.0. was used in order to analyze speed and acceleration of mechanism. Either kinematic simulation of mechanism or orbits can be obtained to input position and length of stripper combs, dimension and angle of four bar linkage mechanism by this software.

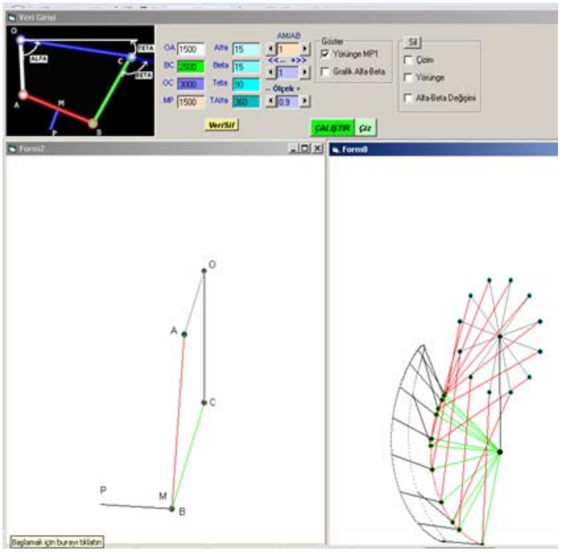


Figure 4. Four bar linkage mechanism and stripper kinematic simulation software

Geometric variables used in kinematic simulation software are illustrated in Figure 5.

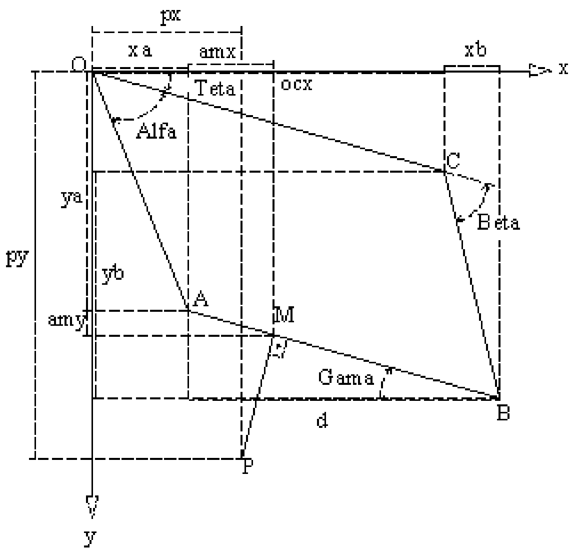


Figure 5. Four bar linkage mechanism geometric variables

Four equations which were used in calculation of coordinates of M and P points of combs on x and y axes had been give the following. These equations had been used to draw motion orbits of used M and P points.

$$px[oa, oc, bc, mp, \alpha, \theta, \gamma] = oa * Cos[\alpha + \theta] + mp * Sin[\gamma] + \sqrt{Cos[\gamma]} * ((oc * Cos[\theta] + bc * Cos[\alpha + \theta] - oa.\,Cos[\alpha + \theta])^2 + (-oc * Sin[\theta] - bc * Sin[\alpha + \theta] + oa * Sin[\alpha + \theta])^2) \quad (1)$$

$$py[oa, oc, bc, mp, \alpha, \theta, \gamma] = mp * Cos[\gamma] + oc * Sin[\alpha + \theta] + \sqrt{Sin[\gamma]} * ((oc * Cos[\theta] + bc * Cos[\alpha + \theta] - oa. Cos[\alpha + \theta])^2 + (-oc * Sin[\theta] - bc * Sin[\alpha + \theta] + oa * Sin[\alpha + \theta])^2) \quad (2)$$

$$mx[oa, oc, bc, \alpha, \theta, \gamma] = oa * Cos[\alpha + \theta] + \sqrt{Cos[\gamma]} * ((oc * Cos[\theta] + bc * Cos[\alpha + \theta] - oa. Cos[\alpha + \theta])^2 + (-oc * Sin[\theta] - bc\, Sin[\alpha + \theta] + oa * Sin[\alpha + \theta])^2 \quad (3)$$

$$my[oa, oc, bc, \alpha, \theta, \gamma] = oa * Sin[\alpha + \theta] + \sqrt{Sin[\gamma]} * ((oc * Cos[\theta] + bc * \ os[\alpha + \theta])^2 + (-oc * Sin[\theta] - bc * Sin[\alpha + \theta] + oa * Sin[\alpha + \theta])^2) \quad (4)$$

While a prototype harvest pepper machine was being planning, the following factors had been attention for stripper combs.

- Combs will enter plant's crown from the bottom point and exit motion from plant's crown to out will start from the top point of the plant.
- Combs will contact the plant less during the turning motion therefore comb will preserve damage the plant during the turning motion.
- Average speed of turning motion of comb will be tried higher according to speed of plant combing motion. Therefore death time which will be during the turning motion will be tried lower.

Harvesting mechanism which had been determined its dimensions by contribution the simulation software with a plant model together had been given taking into consideration the above factors (Figure 6.). The middle point of the comb is the orbit which had been drawn in red in Figure 6., had been the P point of comb. Comb middle point is MP point and its orbit blue. The plant body model which were generated from 0.4x0.5 m ellipse had been located above 0.08 m from the land surface referencing the model.

Obtained data from experiments hade been made variance analysis by MSTAT-C software (Crop and Soil Sciences Department, Michigan State University, Version 1.2). They had been applying the test of Duncan according to Bek (1983).

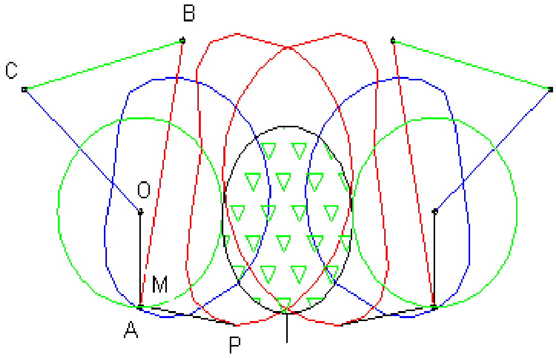


Figure 6. Reciprocal arranged four bar linkage mechanism and orbits of M, MP center and P points

CONCLUSIONS

Force required to remove fruit from the plant was measured on four plant and 30 fruits while the fruit of pepper had been taken directly. The experiment results had been presented in Table 1.

Table 1. 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

The 30 measurements had been shown that the required forces to remove fruit from the plant were very variable range and had changed between 5 to 42 N. Arithmetic average of the force had been taken and the average force value had been calculated as 22 N. Measured forces are believed to give results a wide range depending on factors such as the maturity degree of fruit, branch structure and location of fruit. These results are not very meaningful distiribution but they had shown to be able to realized to harvest fruit with high force by taken directly.

This finding reveals that the harvesting machine which has a mechanism to be harvested pulling pepper fruit would have to apply high forces to plant. Exerting high pulling forces to the plant by harvest mechanism can cause high damage on the plant and can uproot. When the pepper fruits turns up easily leaves the plant from abcission layer on their pedicel. While the stripper fingers is moving up from below the fruit attaches to handle and while they are removing upwards handle from branch remove easily with identifing moment.

Harvesting experiments had been made on single row 10 plants with 15, 20, 25 mm spaced and with experimental harvesting mechanism (Figure 7.)

Figure 7. Experimental harvest mechanism

On the experiments,. designed comb spaced 15 mm had been observed compressing in the plant and giving a quite heavy damage to crops %86 fruit had been harvested by trial experiments in this comb range. However %76 fruit had remained on broken branches and shattered branches. For this reason, the percentage of trash can not be measured not to be able to give a health result. This comb mechanism was always used in harvest working, the forces on it were heavy, comb mechanism had to have the larger comb elements. One of the main aims collects the trash material at minimum quantity. These combs are not suitable for this study aims. When the comb's spaced 25 mm comb had moved easily in the plant it had damaged less to the plant. The combs which moved easily in the plant had harvested %30 of the fruit on the plant. Less amount of leaf and slim stem had been observed according to collected materials. This range of comb also damaged less it hadn't been suited because of low harvest success. 20 mm spaced stripper comb had given the best results. In trial experiments %80 of fruit could be collected and the plant had not damage seriously. The results of the percentage of harvested crop and foreign material made with different spaced combs had been given in the Table 2.

Table 2. Harvest results of experimental harvest mechanism

Comb Space (mm)	Harvested crop (%)	Foreign Material (%)	Note
15	86	*	Damage on main branches and high level foreign material
20	80	8	High harvest success, less amount foreign material
25	30	5	Low harvest success and foreign material

Generally strength, rigidity, cross section and tine space of comb materials had give different results and also impact harvest success. These results hade been presented on Table 3.

Table 3. Properties of tine material and results

Properties of tine material	Results
Unsufficient strength	Bending of tines, easy moving ability of combs
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	Unsufficient strength, less rigidity, easy moving ability of combs
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 combs, lower harvest success

The harvesting experiment of K.Maraş red chilli pepper had been made by prototype harvest machine over the two rows which 20 m lenght. 72% fruit on the plants had been collected in the harvesting experiments. Results had been shown in Table 4. The mos of non-collectable fruits were dry and little fruits.

The harvesting experiment of K.Maraş red chilli pepper had been made by prototype machine over the same two rows with 20 m in October 2007. In trial experiment, tractor advance speed was 0.36 m/s, OA link turning speed was 60 min^{-1} these had been given the best results.

Figure 8. Prototype pepper harvest machine field experiment

72% fruit on the plants had been collected in the harvesting experiments. Results had been shown in Table 4. The most of non-collectable products were dry and little fruits. While the number of revolution increases advance speed depending on it increases however damage on the plant body increase radically. When OA link was turned 30 min^{-1} harvesting success was low. Due to the low rotation speed, plant stems escapes between the combs easily.

Experiments had shown different effects on amount of crop and foreign material, this difference had been found important statisticly ($p<0.05$). Turning speed of OA link had given higher results effects on amount of harvested crop n_2 (%68) and n_1 (%65) had followed it. The same experiment had caused similar results effects on amount of foreign material. Harvester advance speed has given higher results effects on amount of the harvested crop in the first speed. In V_2 speed had been found higher values (%13) according to affected results of foreign material and from the harvester advance speed of foreign material.

Position changing of comb end point (P) depending on the harvest machine speed until arriving from bottom point of plant to the top point of plant to the top had been given in Figure 9.

Table 4. Harvest results of prototype chilli pepper harvester

OA link rotation speed (min^{-1})	Harvester speed (m/s)	Harvested crop (%)	Foreign material (%)
30 (n_1)	0.36(V_1)	68 (d)	7 (d)
	0.47(V_2)	61 (f)	8 (d)
Average		**65 (C)**	**8 (C)**
60 (n_2)	0.36(V_1)	72 (c)	8 (d)
	0.47(V_2)	64 (e)	12 (c)
Average		**68 (B)**	**10 (B)**
90 (n_3)	0.36(V_1)	81(a)	14 (b)
	0.47(V_2)	76(b)	18 (a)
Average		**79 A**	**16 A**
	V_1 Avr.	**74 (A)**	**10 (B)**
	V_2 Avr.	**67 (B)**	**13 (A)**

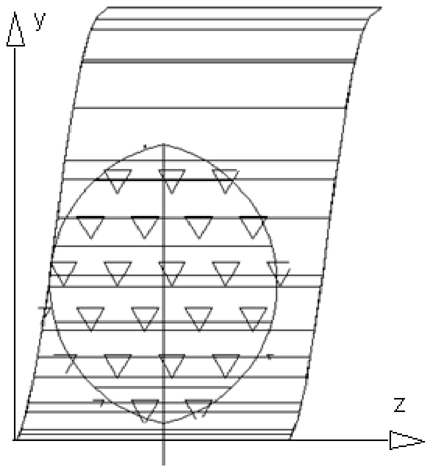


Figure 9. Position changing of comb end point (P) depending on the harvest machine speed (OA link rotation speed 60 min^{-1} , harvester speed 0.36 m/s)

While the position changing was being drawn, the rotation speed of OA link was 60 min-1, harvester speed 0.36 m/s and used numerical data were given in Table 5. If the numerical data are surveyed the comb can changing position 0.19 m according to the bottom start point at the arrived point to the highest of plant. However this point realized over 0.76 m of the bottom start point of plant. Comb end point leaves from plant in 0.3 s of comb action and position changing is 0.11 m at this time.

Figure 5. Positions of comb end point (P) on y and z axis depend on time (OA link rotation speed 60 min^{-1} , harvester speed 0.36 m/s)

t (s)	y (m)	z (m)
0	0	0
0.05	0.039	0.019
0.1	0.10	0.038
0.15	0.19	0.057
0.2	0.28	0.076
0.25	0.39	0.094
0.3	0.49	0.11
0.35	0.58	0.13
0.4	0.66	0.15
0.45	0.72	0.17
0.5	0.76	0.19

Bending front of plant is inevitable due to harvester speed and comb speed on the perpendicular axis. If the harvester speed is increased bending angle of plant will also increase. The comb speed is increased to balance it but the damage increases on the plant therefore between two speed can be seen being a sensible relation. Due to high combing speed study will increase the percentage of foreign material, about sorting and storing problems will increase. However due to forces on comb will increase tine cross-section will need. This will increase cross-section of tines and make the motion difficult.

REFERENCES

BEK, Y., 1986. Araştırma ve Deneme Metodları. Ç.Ü. Ziraat Fakültesi. Ders Notu. Yayın No 92. ADANA.

GENTRY, J. P., MILES, J. A., HINZ, W. W., 1978. Development of a Chili Pepper Harvester. Transactıons of ASAE,52-54.

LENKER, D. H., NASCIMENTO, D. F., 1982. Mechanical Harvesting and Cleaning of Chili Peppers. Trans.Amer. Soc. Agr. Eng.Paper No. 80-1533.

MARSHALL, D. E. 1984a. Mechanized Pepper Harvesting and Trash Removal. Proc. 1st Int. Conf. On Fruit, Nut and Vegetable Harvesting Mechanization, Bet Dagan, Israel. P.276-279. Amer. Soc. Agric. Eng. Publ. 5-84.

MARSHALL, D.E. 1984b. Horticultural Requirements for Mechanical Pepper Harvesting. Proc. 1st Int. Conf. On Fruit, Naut and Vegetable Harvesting Mechanization, Bet Dagan, Israel. P.389-396. Amer. Soc. Agric. Eng. Publ. 5-84.

MARSHALL, D. E., ESCH, T. A. 1986a. Recovery and Damage of Mechanically Harvested Peppers. Trans. Amer. Soc. Agr. Eng. 29:398-401.

MARSHALL, D. E., ESCH, T. A., DRAGT, S. R. 1986b. Influence of Certain Open Helix Variables on Pepper Damage. Trans. Amer. Soc. Agr. Eng. 29(3):714-717.

MARSHALL, D. E., BOESE, B. N., 1998. Breeding Capsicum for Mechanical Harvest, Part2-Equipment. Proc.,10:61-64. 10th Eucarpia Meeting on Genetics And Breeding of Capsicum and Eggplant, Avignon, France.

PALAU, E., TORREGROSA, A., 1997. Mechanical Harvesting of Paprika Peppers in Spain., Chile Task Force. Report J. Agric. Engng Res., 66, 195-201.

SALTON, J. R., WILSON C., 2001. Improving Chile Harvesting and Cleaning Technologies., New Mexico Chile Task Force. Report 6.

WOLF, I., ALPER, Y., 1984. Mechanization of paprika harvest. In Proc. Int. Symposium on Harvest Mechanization of Fruit, Nut and Vegetable Harvesting Mechanization, 265-275 (Oct.) Bet Dagon Israel. ASAE Pub. No 584.