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DEVELOPMENT OF A CHOPPER UNIT FOR CHOPPING OF SUNFLOWER STALK DURING HARVESTING BY COMBINE HARVESTER

I. S. DALMIS[1], B. KAYISOGLU[2], Y. BAYHAN[2], P. ULGER[2], F. TORUK[2] and F. DURGUT[2]
[1] *Namik Kemal University, Faculty of Engineering, Department of Machine Engineering, Corlu, Tekirdag, Turkey*
[2] *Namik Kemal University, Faculty of Agriculture, Department of Biosystems Engineering, 59030 Tekirdag, Turkey*

Abstract

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The aim of this research was the development of a chopping unit, which is placed under the header of a combine harvester. In this way, stalks can be chopped during harvesting and this will be useful in respect to saving time, labor, and energy. In addition, field traffic will decrease by using this unit.The alternative chopping unit may replace the conventional methods. For this objective, the developed chopping unit was tested in three different types of chopping methods. These methods were called Machine 1, Machine 2 and Machine 3. All methods were tested with two and three blade modules.

The best results were obtained with 3 flat blades modules on Machine-2. While the average stalk size of Machine-2 was 14 cm, this value was 9.6 cm in 3 flat blades. With this machine the surface covering rate was 26.25%, the average height of stalk was 11.53 cm.

This paper describes the structural features of the machine, the design of the main working parts, determination of the parameters of the position of the blade modules, and presents the performance tests.

Key words: Chopping, chopping blade, sunflower stalk

Introduction

In the last decades, the perception of the relationship between agriculture and environment has changed remarkably and concerns have been raised about the sustainability of agricultural production systems (Bechini and Castoldi, 2009; Pacini et al., 2002, 2004)

Conventional management based on agricultural practices such as straw-burning and excessive tillage increases soil erosion and compaction that contribute to soil fertility loss. For that reason, profitable and respectful environmental agricultural practices such as conservation agriculture are being promoted in the European Union (Melero et al., 2008).

According to Jilin Province Agricultural Scientific Academy's (2003) data, In the ridged cultivation area of northeastern China, the conventional mechanized farming system has resulted in a decrease in the soil organic matter year by year (an annual average decrease by 0.01–0.02%) (Honglei et al., 2007).

The stalk–stubble breaking and mulching process is most common technique for some conservation tillage system. During harvesting which is one of the most important stages of plant production, protection and improvement of physical and microbiological structure of the soil are achieved by chopping the plant residue that stays in the field and then mixing them with soil. Besides, seedbed preparation and sowing stages became easier through this process.

In this research a chopping unit, which is placed under the header of a combine harvester, was developed. The developed chopper unit field-testing was done in Trakya Region. According to 2009 data of Turkish Statistical Institute, the results of the Crop Production Survey, In terms of sown field area, ratios of sunflower are with 4.3% (Tan, 2010) and Tekirdag province is Turkey's largest sunflower production

E-mail: idalmis@nku.edu.tr

area with 1.293.361 ha. Stalks of sunflower plant that is grown in Trakya Region especially in Tekirdag province are left in fields after harvesting. These stalks are more difficult to chop and mix than those of other field crops such as cereals due to their dimension and texture properties. Furthermore, deterioration of these stalks takes a long time, therefore small stalk parts are preferred. For this reason, some soil tillage equipment such as rotary cultivators and disc harrow are used in this region. However, all of this equipment must be operated after harvesting and additional technological process is required.

Materials and Method

Chopper unit

In this study, ClaasLexion 530 harvester was used with 4.2 m work width sunflower header. The sunflower header is manufactured specifically for this research. Header working width dimension is determined to be 6 lines of sunflower harvest. Sunflower seed row spacing is commonly 70 cm in the region. Therefore, the chopper unit working width was determined 2190 mm in terms of manufacturing and ease of use. A chopper unit can chop 3 rows of sunflower stalks with this working width. Two chopper units are placed under the cutter bar of the header. Every group of chopping units includes 3 chopping blade modules and the number of groups can be changed according to working width of the combine harvester. The chopper unit consists of a main body, a main shaft, three bevel gears mechanisms, four bearings and three blade modules.

The chopper Unit is driven by the engine of the combine harvester and movement is transferred to the axle that carries the chopping elements by using a chain transmission mechanism and transmission box. The transmission increases the lower engine speed to the higher blade speed, decreasing torque in the process. Movement is transferred to the chopper unit main shaft with a chain drive mechanism. Transmission box input rotation speed is 580 rpm and output rotation speed is 2443 rpm. The chopper unit has three bevel gear mechanisms. These bevel gear mechanisms raise the main shaft rotation speed 1396 rpm to 2443 rpm. Figure 1 show the chopper units and the transmission box gears system location on sunflower header.

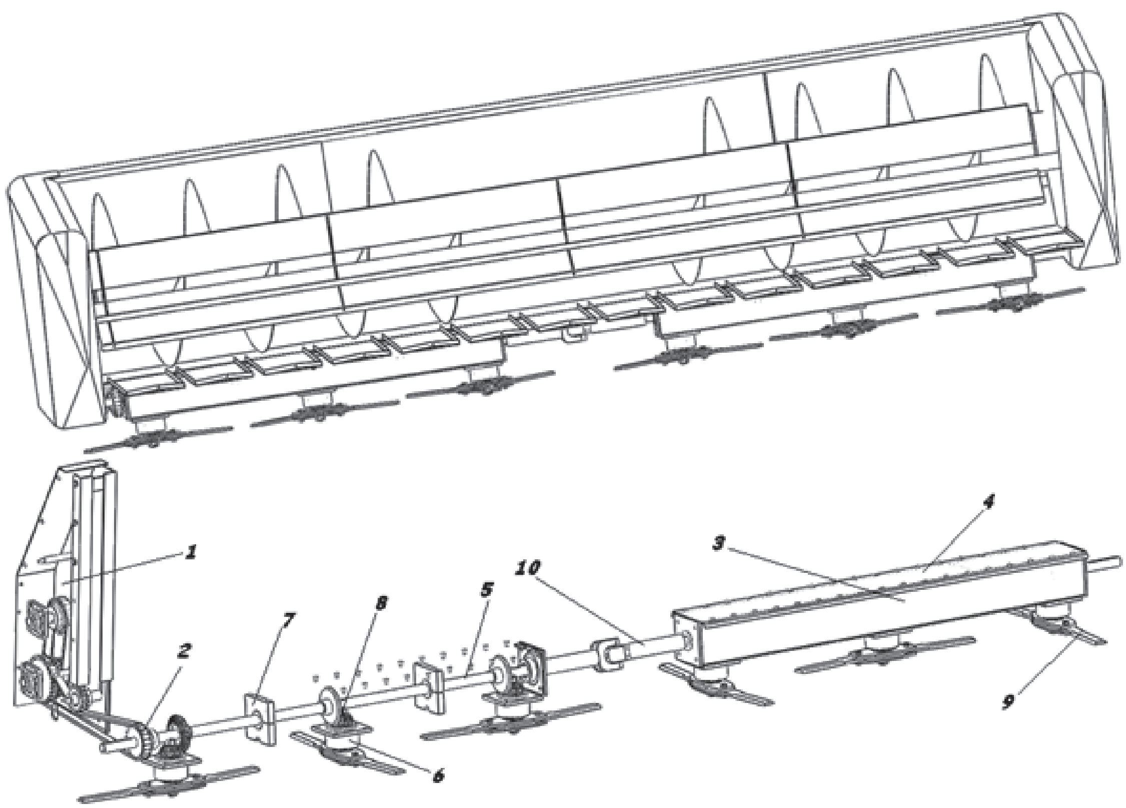

Fig. 1. The header of combine harvester and 2 chopper units:
(1) The transmission box; (2) chain gear; (3) main body; (4) main body cover; (5) main shaft; (6) blade modules; (7) bearings; (8) bevel gears mechanisms; (9) blades; (10) connection shaft

Bladesand blade modules

Two types AISI 9260 spring steel flat and curved blades used in the study are 40HRC hardness. Blade dimensions are shown in Figure 2.

Blades were used with blades modules (Figure 3). These modules have 2 types which are called two blades module and three blades module. Blade modules are driven by bevel gear mechanisms which are on the main shaft. A blade module consists of: a body, a blade shaft, bearings, a blade holder cap, a blade shaft nut, blades and blade holders bolts and nuts. Blade modules are fixed to the main body by screws.

Chopping methods

The developed chopping unit was tested using three different types of chopping methods respectively. These methods were called Machine 1, Machine 2 and Machine 3. For all methods blades rotation speed was held constant 2443 rpm. In machine 1, chopper blade modules were separated from each other as a cell by flat divider sheets and circular rubber curtains.

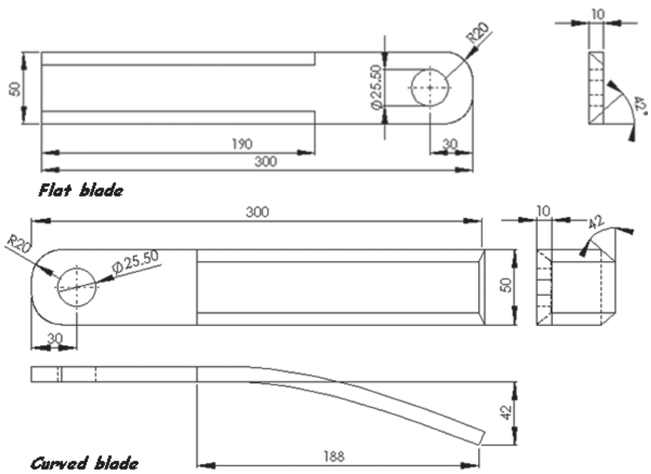

Fig. 2. Blade dimensions

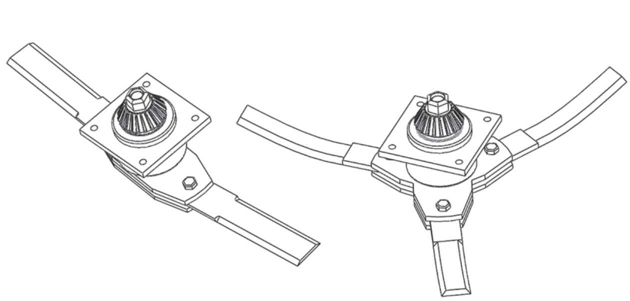

Fig. 3. Two and three blades modules

In machine 2, Chopper blade modules were not separated from each other as a cell. Only a flat rubber curtain was used in the rear side of the blade modules.

In machine 3, chopper blade modules were separated from each other as a cell by circular divider sheets and circular rubber curtains.

In machine 1 and machine 3, circular curtains were used in the rear side of the blade modules. The purpose of the dividers and rubber curtains were used to prevent the escape of the piece of the stalks on blades (Figure 4).

Test methods

Power measurement

Power cunsumption of the system was measured with a torque meter (Digitech, 2000 Nm) which is placed between the combine harvester and gear box shafts. The torque meter data was transferred to the computer by a data logger (Delta-T).Installation of the torque meter is shown in Figure 5.

Field studies

Field studies were carried out at Gallipoli, Tekirdag and Kirklareli in accordance with the planned experimental pattern. Tunca sunflower variety was used in the study. The measurement of moisture in the stem samples taken from the field the average humidity was 27.4%.

Chopped stalk sizes, heights of harvesting, stem distribution rates, shapes and dimensional features of sunflower stalks and power consumptions were measured in the field experi-

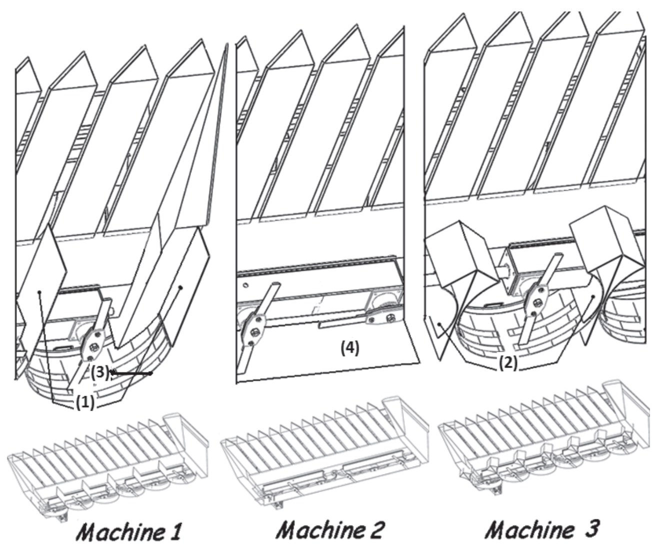

Fig. 4. (1) Flat divider sheet; (2) Circular divider sheet; (3) Circular rubber curtain; (4) Flat rubber curtain

ment. The combine harvester velocity used in the filed experiments was 7 km/h.

The experiment pattern

Before the harvest, fields were divided into parcels. Experiments were made in 10mx50m parcels with 3 replicates. Experiments were made with 3 factor (3x2x2) factorial experimental design (Kocabiyik, 2003; Kayisoglu et al., 2006). Results of variance analysis were made with MSTAT statistical package program.

The plant heights were measured with a tape measure on the parcels. Plant stem diameters were measured with calipers.

After the harvest, the frame method (1m^2) were used to measure the dimensions of the stalk pieces on the field surface. In this method the frame was placed on field surface randomly and the chopped stalks dimensions were measured by a tape measure in the frame.

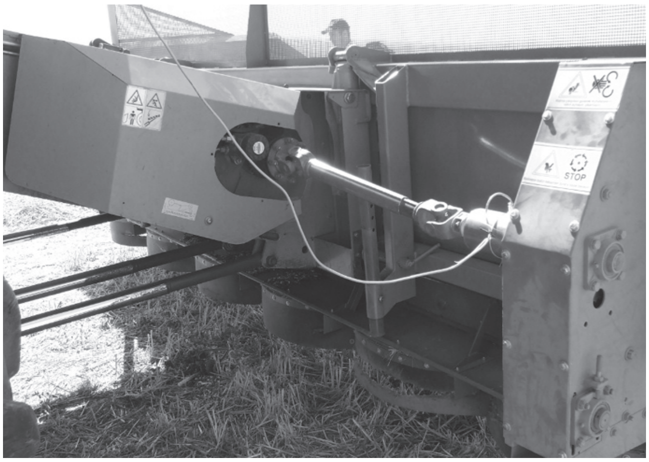

Fig. 5. Installation of the torque meter

The harvesting height was determined by measuring the height of the remaining stalks in the field with a tape measure.

After harvest, the chopped stalk covering rates on the surface of field were determined by the linear line method. In this method, the markings were made at intervals of 20 cm over 20 m long rope. The marked rope was placed on the harvested field surface at a 45° angle and chopped stalks in contact with marked points were counted.

Results and Discussion

Chopping efficiency was determined for the most appropriate combination of chopping. The results of the experiments are given below in the order specified in the method section. Pre-harvest an average height of stalk and average diameter of stalk was found to be 120.5 cm and 19.78 mm respectively. The mean stem densities were found 6550.4 units/da, in terms of weight 420.1 kg/da, rootless 300.4 kg/da.

Post-harvest measurements

Determined piece-size distributions of post-harvest

Statistical evaluation data related to the piece size distributions have been given in Table 1. The lowest mean value was 9.6 cm which was obtained with Machine 2 that had 3 flat blade modules. The highest mean value was 20.2 cm which was obtained with the machine 3 that had 2-flat blades. The joint effect of machines, blade types and blade numbers (A *

Table 1
Average piece size

A	B	C	Average		
			(A*B*C)	(A*B)	(A)
Machine-1	Flat	2	16.6 ^{bcd}	17	16.63 ^{a}
		3	17.4 ^{abc}		
	Curved	2	15.1 ^{cde}	16.25	
		3	17.3 ^{abc}		
Machine-2	Flat	2	16.6 ^{bcd}	13.1	14.00 ^{b}
		3	9.6 ^{f}		
	Curved	2	14.0 ^{cde}	14.9	
		3	15.8 ^{bcd}		
Machine-3	Flat	2	20.2 ^{a}	16.25	16.23 ^{a}
		3	12.3 ^{ef}		
	Curved	2	13.2 ^{de}	16.2	
		3	19.2 ^{ab}		

A: Machine type, B: Blade type, C: Number of blade, LSD (A*B*C) = 3.435, LSD (A) = 1.718

B * C interaction) was statistically significant (F = 7.32 **) on the particle-size distributions. In addition, the difference between the machines were significant (F = 5.83 **). Machine-2 was put into a separate group than others with lower average piece size of 14.0 cm. Statistically, 3 flat blade module and 2 curved blade module were in the same group while making of groups without the influence of the machines (B * C interaction).

The highest coefficient of variation value of 58.4% was found with 2-flat-blade modules on the machine-1. In addition, the lowest coefficient of variation value of 33% was found with 3 curved blade modules on the machine-1 (Table 2).

Surface covering rate

After chopping process surface covering rates are shown in Table 3. Machine types effect on the surface covering rates is statistically significant (F=16.97**). Machine-1 and machine-3 are in the same group but machine-2 has formed a separate group with the highest value of surface covering (26.25%).

In addition, the joint effect of the machine type and number of blades' (A * C interaction) effect on the ratio of surface covering was significant (F = 33.44 **). The highest surface-covering rate of 27.80% was found with 2-blade chopping modules on machine-2 (Table 4). Blade types (F11. 95 **) and the number of blades (F = 33.44 **) have been important effect on surface covering ratio. Flat blade surface covering rates were

Table 2
Piece-size distributions of the maximum, minimum values and the coefficients of variation

A	B	C	Max.	Min.	Ave.	SD	CV %
Machine-1	Flat	2	43	4	16.6	9.7	58.4
		3	29	5	17.4	5.9	33.9
	Curved	2	30	5	15.1	6.8	45
		3	30	8	17.3	5.8	33.3
Machine-2	Flat	2	39	4	16.6	8.7	52.4
		3	46	3	9.6	8.4	87.5
	Curved	2	28	5	14	5.5	39.3
		3	31	5	15.8	6.9	43.7
Machine-3	Flat	2	64	3	20.2	10.8	53.5
		3	37	4	12.3	6	48.8
	Curved	2	38	4	13.2	7.7	58.3
		3	50	7	19.2	9.9	51.6

A: Machine type, B: Blade type, C: Number of blade

Table 3
Surface covering rate (%)

A	B	C	Average		
			(A*B*C)	(A*B)	(A)
Machine-1	Flat	2	26.1	22.7	21.30 ^{b}
		3	19.3		
	Curved	2	20.1	19.9	
		3	19.7		
Machine-2	Flat	2	31.5	29.55	26.25 ^{a}
		3	27.6		
	Curved	2	24.1	22.95	
		3	21.8		
Machine-3	Flat	2	24	19.8	19.30 ^{b}
		3	15.6		
	Curved	2	25.3	18.8	
		3	12.3		

A: Machine Type, B: Blade Type, C: Number of blade found higher (24.02%). In addition, the surface covering had been high percentages (25.18%) in 2-blade systems.

Table 4
A*C Interaction

Machine (A)	Number of Blade(C)	Average
Machine-1	2	23.10 [bc]
	3	19.50 [c]
Machine-2	2	27.80 [a]
	3	24.70 [ab]
Machine-3	2	24.65 [ab]
	3	13.95 [d]

LSD(A*C) : 3.603

Chopping height

After chopper, the average heights of the remainder of the sunflower stalks at field are given in Table 5. Difference between machines was significant (F=56.26**). Each machine type formed separate group. The lowest chopping height 1.53 cm was found with Machine-2. In addition, the effect of the blade types was found important on chopping height. (F=11.28**).

Power consumption

There was no statistically significant difference betweenthe power consumption of the Machines (F=0.27). In addition, all interactions were insignificant effect (Table 6).

Table 5
Chopping height (cm)

A	B	C	Average		
			(A*B*C)	(A*B)	(A)
Machine-1	Flat	2	14.1	15.15	16.25 [b]
		3	16.2		
	Curved	2	18.5	17.35	
		3	16.2		
Machine-2	Flat	2	11.5	11.05	11.53 [c]
		3	10.6		
	Curved	2	12.5	12	
		3	11.5		
Machine-3	Flat	2	16.6	17.2	18.43 [a]
		3	17.8		
	Curved	2	19.9	19.65	
		3	19.4		

A: Machine type, B: Blade type, C: Number of blade, LSD (A) = 1.379

Table 6
Power consumption (kW)

A	B	C	Average (A*B*C)	Average (A*B)	Average (A)
Machine-1	Flat	2	9.7	10.05	10.85
		3	10.4		
	Curved	2	11.5	11.65	
		3	11.8		
Machine-2	Flat	2	9.5	9.7	10.48
		3	9.9		
	Curved	2	10.9	11.25	
		3	11.6		
Machine-3	Flat	2	10.1	10.55	11.18
		3	11		
	Curved	2	11.5	11.8	
		3	12.1		

Table 7
Fuel consumption (l/h)

A	B	C	Average (A*B*C)	Average (A*B)	Average (A)
Machine-1	Flat	2	0.82	0.86	0.91
		3	0.89		
	Curved	2	0.95	0.97	
		3	0.98		
Machine-2	Flat	2	0.81	0.83	0.88
		3	0.84		
	Curved	2	0.91	0.93	
		3	0.95		
Machine-3	Flat	2	0.87	0.9	0.97
		3	0.93		
	Curved	2	0.99	1.04	
		3	1.09		

A: Machine type, B: Blade type, C: Number of blade

Fuel consumption

Average values of the consumption of fuel are given in Table 7. Fuel consumption was not significant between the machines (F=0.96). Fuel consumption has been significantly between types of blades (F=4.58*). Fuel consumption with flat blades was less (0.86 l/h).

Conclusion

In the statistical evaluation of measurements, machine 2 were obtained with the best results, in terms of stalk chopping sizes (Table 1), the surface covering (Table 3) and chopping heights (Table5). In terms of power consumption (Table 6) difference was not observed between all three machines. However, In terms of power consumption, (Table 6) difference was not observed between all three machines but statistically flat blades were found better than curved blades. Stalk shredding dimension is one of the most important parameters of the research. In terms of stalk shredding dimensions flat blades was found more successful. The best results were obtained with 3 flat blades modules on Machine-2. While the average stalk size of Machine-2 was 14 cm, this value was 9.6 cm in 3 flat blades. With the machine the surface-covering rate was 26.25%, the average height of stalk was 11.53 cm. Using of divider sheets between the chopping blades prevents the other blades chopping effect. This decreases the effectiveness of the chopping.

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References

Bechini, L. and N. Castoldi, 2009. On-farm monitoring of economic and environmental performances of cropping systems: Results of a 2-year study at the field scale in northern Italy. Ecol. Indicat., doi:10.1016/j.ecolind.2008.12.008

Honglei, J., M. Chenglin, L. Guangyu, H. Dongyan and L. Zhaochen, 2007. Combined rototilling-stubble-breaking-planting machine. *Soil and Tillage Research*, **96:** 73–82.

Jilin Province Academy of Agricultural Sciences, 2003. Acceptance document of new technological transformation and pilot test of matching agricultural machinery for corn culture.Working report, pp. 1–5 (Ch).

Kayisoglu, B., Y. Bayhan, E. Gonulol, H. Kocabiyik and I. S. Dalmis, 2006. The Evaluation of Suitability in Point of Energy Costs of Rotary Type Stalk Shredders, Trakya University Research Project (TUBAP-606), Final Report, Tekirdag.

Kocabiyik, H., 2003. A research on sunflower stubble chopping, design and manufacture of a prototype machine for stubble chopping. Ph.D. dissertation. Trakya University, The Institute of Natural and Applied Sciences, Agric. Machinery Mainsci. Section. Turkey.

Melero, S., K.Vanderlinden, J. K. Ruiz, E. Madejon, 2008. Long-term effect on soil biochemical status of a Vertisol under conservation tillage system in semi-arid Mediterranean conditions. *European Journal of Soil Biology*, **44:** 437–442.

Pacini, C., A. Wossink, G. Giesen, C. Vazzana and R. Huirne, 2002. Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and fieldscale analysis. *Agric. Ecosyst. Environ*., **95:** 273–288.

Pacini, C., A. Wossink, G. Giesen and R. Huirne, 2004. Ecological-economic modeling to support multi-objective policymaking: a farming systems approach implemented for Tuscany. *Agric. Ecosyst. Environ*., **102:** 349–364.

Tan, A., 2010. Second National Report of Turkey on Conservation and Sustainable Utilisation of Plant Genetic Resources for Food and Agriculture, Izmir, Turkey.

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