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INDUSTRY-PEPPERS HARVEST MECHANIZATION

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ABSTRACT

Production of peppers for dehidration (paprika) and for extraction of natural colorants is of great importance in some Mediterranean irrigation areas. In the area of Badajoz (Spain) traditional production, handling and postharvest systems are no longer feasible, although a very good quality and potential market exist for this product.

All aspects of mechanized production and handling have been addressed: direct seeding and transplanting, cultivation systems and mechanical harvesting are searched to be adopted in a new production system.

A study of size, shape and fruiting pattern of the new varieties was performed. A feasibility study of mechanized harvesting was also made.

Results of field testing of different types of harvesters and performance of existing picking heads are presented, some of which yield a feasible solution for the growers of industry peppers in the area. The design, construction and field testing results of a new picking head, based on the double-helix principle is presented.

1. PROBLEMS OF INDUSTRY-PEPPERS IN SPAIN

Volume of industry-pepper production is in Spain in the order of 150000 t; from these, 23000 t are dehidrated and grownd to paprika powder. There are two main production areas: Murcia (at the SE, producing a 60% of the total) and La Vera (28%). The rest is spread in all parts of the country.

Spain exports "sweet", "semi-sweet" and "hot" paprika, whereas most of the imported paprika is of the hot quality, because Spanish production is very low in comparison to the other qualities. The production surface of hot is decreasing. Most of the imported paprika comes from China, Pakistan, Indonesia, Nigeria and India (Bartolomé, 1989).

The EC is a very important potential market for Spanish paprika, and it creates the need for restructuring the whole production sector. Over 50% of the paprika grown in Spain is exported, most of it grown in Murcia. The reason for this comes from the flavor differences. In La Vera, fruits are dehidrated "in situ" by the growers, during a long harvesting period of time in wood burners; this gives to paprika the traditional "smoked" flavor. This flavor and the low dimension of producers causes a very low export market, so that between 90 and 95% of this production is sold to internal market. In Murcia, dehidration is performed largely in undustrial dehidrators, using conventional fuels, once the fruit is harvested and partially sun-dehidrated. Growers are largely associated in larger cooperatives for this purposes.

Apart from paprika powder, an increasing interest appears for "oleoresines", a very significant product for the food industry (natural food-colorants).

Very important changes are occurring in the sector during the last years, due to lack of development and modernization of production systems, with the need of important technology inputs. In these, Agricultural Engineering was felt to be able to give solutions for many of the problems encountered in this necessary transformation.

Traditionally, paprika pepper is grown in the furrow system, with seedling production and tranplantig. Nowadays, with the use of plastic mulching, direct seeding and, eventually, localized irrigation, there exist different sustainable production systems: a) surface irrigation combined with plastic mulching; b) furrrow irrigation without mulching, c) localized irrigation with and d) without mulching and e) sprinkler irrigation (Bañon, 1991).

Paprika pepper varieties grown in Spain are of different types: round fruit ("Ball"), subspherical fruit and elongated fruit ("Ocal"); they consist of mixtures of several lines which have evolved differently in the different growing areas. All local types are well adapted to climatic conditions, but show a very long ripening time lapse; maturation of the fruits is in presdent conditions not concentrated at all. New varieties are being introduced, and they have been tested as to their ability for mechanical cultivation and harvesting. Varieties like "Buketen" "Bukano" and "Bubar" show low plant productivity in our latitudes and have to be sown at high densities.

The reduction of hand labor in agriculture in the EC, still a need in our traditional agricultural areas, leeds again to the necessity of mechanizing paprika pepper production. New technologies in the production phase are centered in two main operations: field implantation of the culture (seeding or transplanting) and harvest.

2. MECHANIZATION OF SEEDING AND TRANSPLANTING

From the traditional seedling production and manual transplanting system a shift is oriented to a) mechanized tranplanting or b) direct seeding.

Mechanized transplanting can be accomplished using conventional transplanters working with free-rooted plants, with which a 6 to 8 times higher work efficiency is obtained in comparison to manual field-setting. Hand-fed machines, of one (40-45 plants/min) or more workers (65-70 plants/min) can be used. With these machines a plant density as high as 100000 plants/ha can be reached, and a sustantial additional work for seedling production under cover (greenhouses) is needed.

Direct seeding of peppers in the field shows a very high potential of reducing hand-labor and costs. Conventional seeders, planting groups of 2-4 seeds, or precision seeders can be used. Depth of seeding is 3-4 cm, at distances 0.3-0.4 m in rows 0.6-1 m apart; for high densities, distances of 0.08-0.1 m in rows down to 0.25 m apart. In Spain, direct seeding of paprika peppers is not solved yet. Different factors affecting seed emergence (seeding dates, soil temperature, depth, size/weight of individual seeds, soil types) are being studied. The test results have not been very challenging when plastic mulching was not used; in the traditional soils, hard crusts and dehidration affect the emergenge negativelly. Using plastic mulching, an emergence of up to 90% has been obtained, with a better growth of the plants, as compared to transplants (Alcaraz and Costa, 1982). In La Vera, not using plastic mulching, 79 % emergence was obtained in light soils; only 60% in heavier soils (Table 1) (Rodriguez and Ayuso, 1988). Days to emergence vary around 22 days for light soils, around 39 days in heavy soils. These are very long times, and the risk of loosing the crop before emergence is then very high. This results point to the possible advantages of transplanting, although it is known that this method has higher costs, higher investment and problems. Rationalization of seedling production and mechanical transplanting operation seems therefore still promising.

3. MECHANIZATION OF HARVEST: PLANT TYPES, HARVESTER FIELD TESTS. COST EVALUATIONS.

Harvest is the most hand labor consuming operation. Therefore, production is definitely led towards mechanical harvesting.

3.1. PLANT MATERIAL

Mechanical harvest forces to use new plant materials which conform to the machines and which show concentrated maturation of the fruits for once-over harvest.

Tests have been carried out with pepper plants of the varieties: A) "Buketen", direct seeded at two different plant densities: 95000 plants/ha (rows at 0.40 m) and 340000plants/ha (rows at 0.20 m). Yields were 8500 and 14000 kg of fresh fruits (app.80% moisture) respectively. B) "Ocal", transplanted and cultivated the traditional way, in rows at 0.75 m and yield of 12000 kg/ha (Figure 2).

Variability of plant size and fruit disposition in the plants was very high. Measurements were carried out in the new variety "Buketen" and in Table 2 the results are summarized.

In plantings at 40 cm - rows, four different types of plants were found: with one, two, three or four levels of fructification, in the proportions 47%, 33%, 13% and 7% respectively. Table 2 shows that, in multiple-level plants, most of the fruits are distributed at 17 - 24 cm height; at the height of 22-23 cm, average number of fruits is 8 fruits/plant.

In plantings at 20 cm - rows, also four types of plants are produced: one and two levels (36.5%), three levels (17 %) and four or more (10%). Most of the fruits (70-80%) are distributed at 25-31 cm height, with an average number of 5.4 fruits/plant at this level.

These results show that plants and fruit insertion are higher at higher densities, and at the same time fruiting concentrates in time and position in the plant. Yields are also higher at the higher tested density.

Detachment force of the fruits was also measured, being 5.2 N the maximum and 3.8 N the average values. Fruits in this type of variety are erect.

For the other variety, the local "Ocal", plants are of 60-70 am in height, and the height of fruit insertion is 18-20 cm. Average yield is 20000 kg/ha. Fruits are pendent, and by selection measures only one fruiting level with 95 % of the production (Figure 3) and concentrated in one harvest, has been obtained by combination of selected plant density with agronomic conditions, like irrigation scheduling and fertilizing practices.

3.2. MECHANICAL HARVESTING FIELD TESTS

During the harvests of 1989 and 1990 mechanical harvesting field tests were carried out in Badajoz, with two machines, both using the "combing" principle: a rotating drum with fingers combs the plants and produces the detachment of the fruits and most of the leaves; this is the principle used for harvesting green beans and other similar products (faba beans, green peas).

Two machines were tested on the first year: (1) FMC mounted on a tractor of 78 kW. The picking head was able to harvest six rows planted at 40 cm (2.4 m); (2) ASA-LIFT model GB 100, hidraulically driven through the tractor-pto (minimum power 35 CV) and working in only one row (Figure 4). The varieties in which tests were performed were the above mentioned: "Buketen" and "Ocal", with following results:

* "Buketen": On lines planted at 40 cm the one-row harvester (2) showed fruit losses mounting up to 20%: 17% on the soil; 3% on the plant (Table 3). For planting distance 20 cm losses were higher, 41%, when working on two rows at a time; distribution of losses was in this case: 28.3% on the soil, 9% on the plant and 3% on the machine trash. The 2.4 m harvester (1) caused, in 40 cm spaced plantings, 34.2% losses: 23.3% on the soil, 10.9% on the plant; in 20 cm plantings, 20% losses: 13.2% soil, 6.8% plant. In the harvested product, a significant presence of green materials (leaves and stems) was found (very variable: 11 to 32%). Sound and red fruits were in the proportion of around 90%, a very good quality of the harvested product (Table 4).
Quality of the harvested product (Table 7) is enough for paprika pepper: it is cleaned of leaves and cut to pieces in the industrial plant.
These results show that mechanical harvest with combing machines

is technically feasible, and can be readily introduced. Although losses may be high in some circunstances, with an adequate preparation of the culture and regulation of the machines, they can be reduced. Field efficiency was 0.198 ha/h for the frontal machine (1) and 0.035 ha/h for the one-row machine (2)(Table 5).
* "Ocal": The test results with this variety, harvested with the one- row machine, two velocities were used: 2 km/h and 1.2 km/h. Losses were 25% in both cases, with some differences in their distribution (Table 6): higher travel speeds cause higher plant losses. Field efficiencies of 0.07 ha/h (v=1.2 km/h) and 0.1 ha/h (v=2 km/h) was obtained.

It seems that, for the small grower, the one-row machine is feasible for present conditions, and therefore it will be introduced in the present harvest (1992), as no hand labor is available. For larger planting surfaces, as they may be established in the next years, larger, more efficient harvesters will be sought.

A new design of picking head, based on the stripping principle is being constructed. It consists of two double helices, already used by other researchers in the USA (Marshall, 1981) and Israel (Wolf, 1984). First tests show very good results in the detachment of pendent-fruited varieties (Figure 5). Some problems with the plant feeding were encountered, which will be solved in this year's model. This new picking head can be mounted directly on the one-row machine, therefore using all its conveying and cleaning systems, as well as loading (into bags).

3.3. ECONOMIC FEASIBILITY

Before the adoption of a mechanical harvester is decided, an economic evaluation has to be carried out as to the feasibility of introducing it in the production system (O'Brien, 1983).
Table 9 includes the average conditions for which the cost formulation and the simulation have been performed. Table 10 shows the results of the analysis. The conclusion is that mechanical harvest of paprika peppers competes economically with manual harvesting, for the present conditions and productions.

Costs have been calculated for different levels of two main parameters:
a) percentage of losses (0 to 30%)
b) prize of the machine (3.5-4.5 million pta=27500 to 35500 ECU), and in three conditions for the machine capacity: (1) optimistic, (2) average, (3) pesimistic (see Table 10) (Buketen: 0.03; 0.04; 0.05 ha/h; Ocal: 0.06; 0.09; 0.12 ha/h); and for the annual machine use (100, 150 and 200 h/year). Production was also introduced at varying levels, but the only results shown are calculated for the average production in the area: 20000kg/ha of fresh product. Manual harvesting costs were 13 pta/kg (1989) and 20 pta/kg (1991). Table 10 shows that, even for field losses of a 30%, machine harvest is competitive with hand harvest for work efficiencies similar to the ones observed in the field tests, and for a production of 14000 kg/ha; this is true in any case for cv. Ocal, and only for average and optimistic conditions for cv. Buketen.

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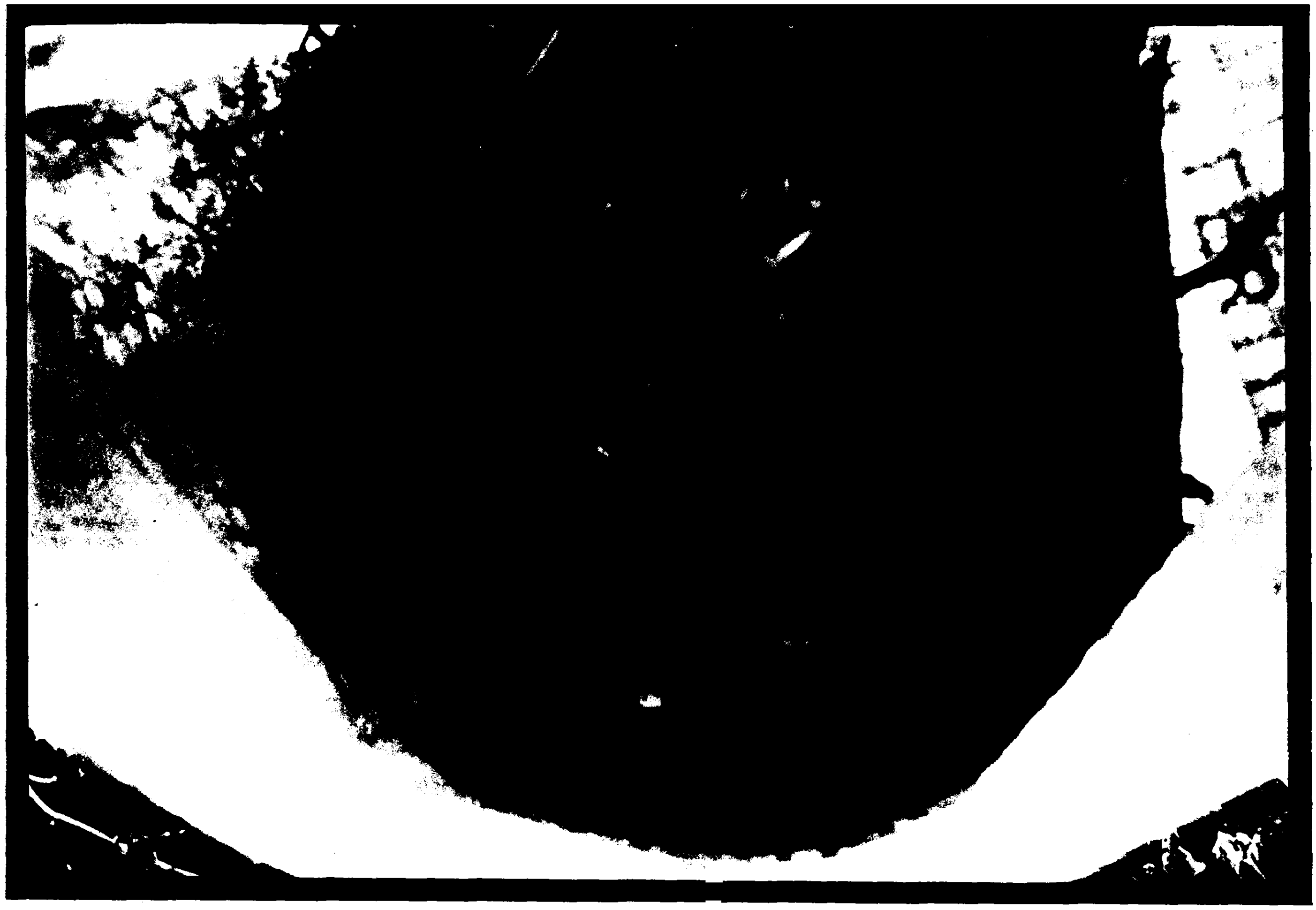

Figure 1. Paprika pepper cultivar (= group of types/varieties) BOLA.

Figure 2. Paprika pepper cultivar OCAL, grown in lines 40 cm apart, transplanted.

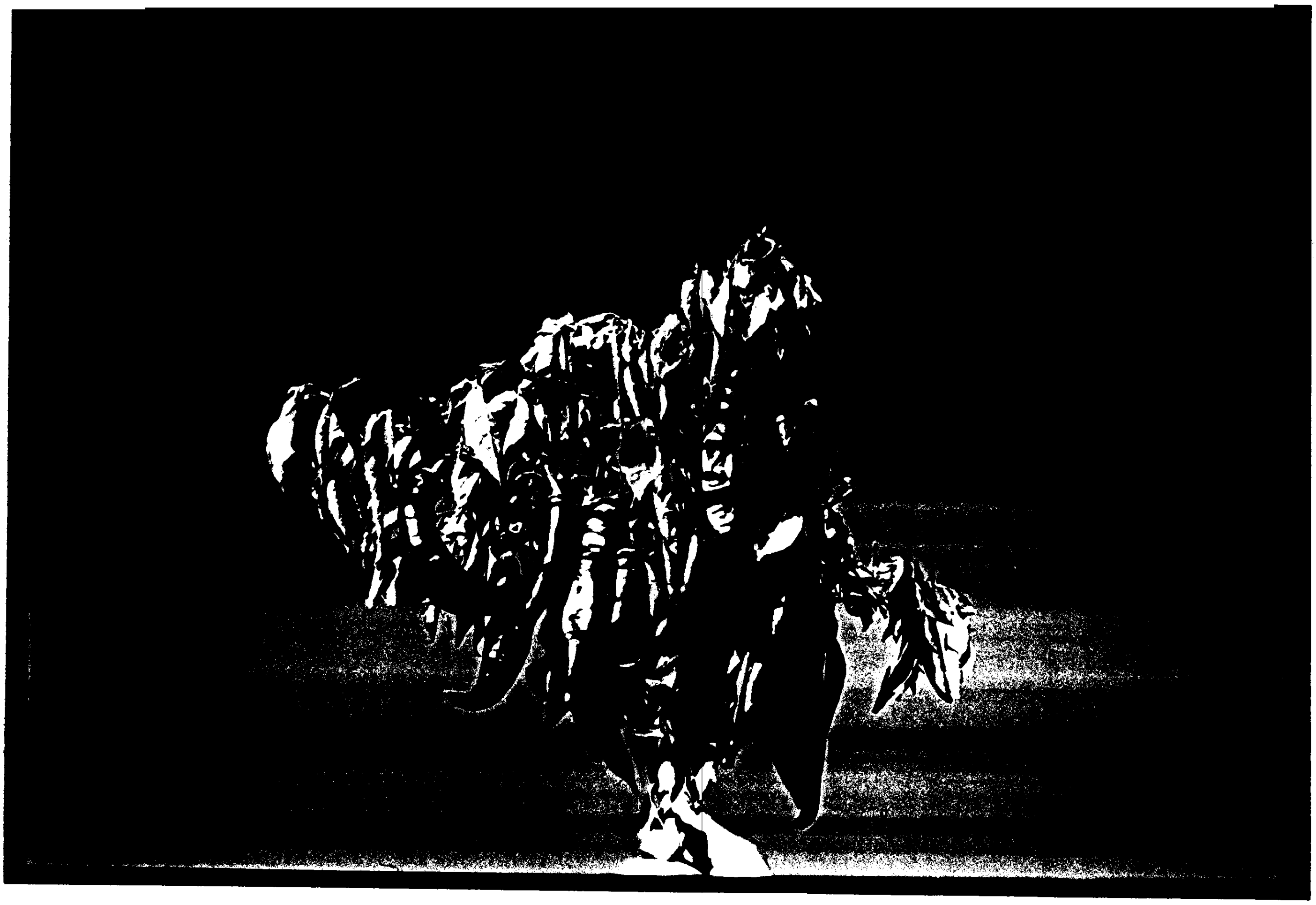

Figure 3. OCAL Plant type. Fruits are pendent. Only one fruiting level with very good maturity concentration.

Figure 4 One-row paprika-pepper harvester. it is tractor-trailed and pto driven. Fruits are loaded into bags.

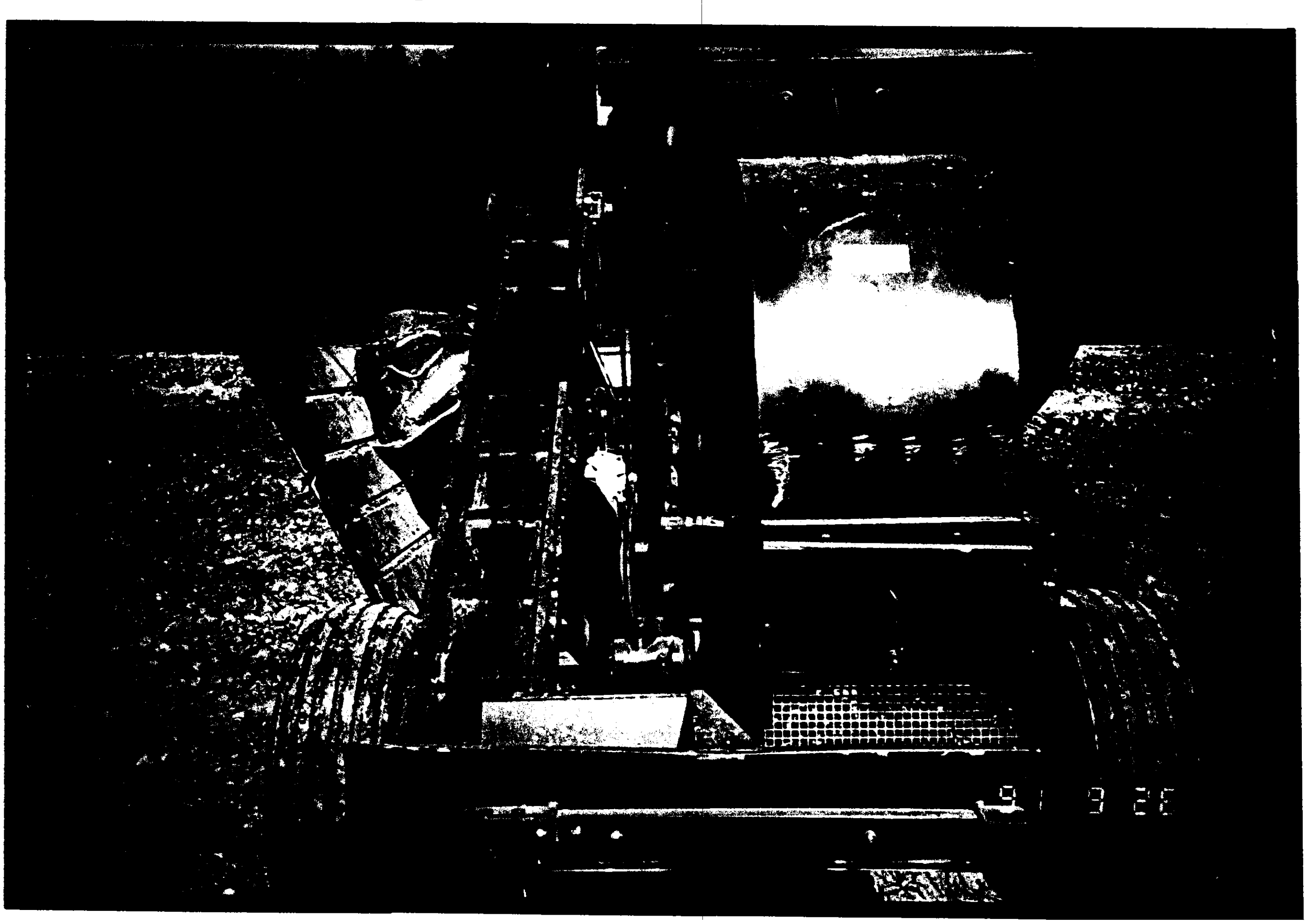

Figure 5. Prototype of new paprika-pepper picking head. Detachment of fruits was total when tested in the shop.

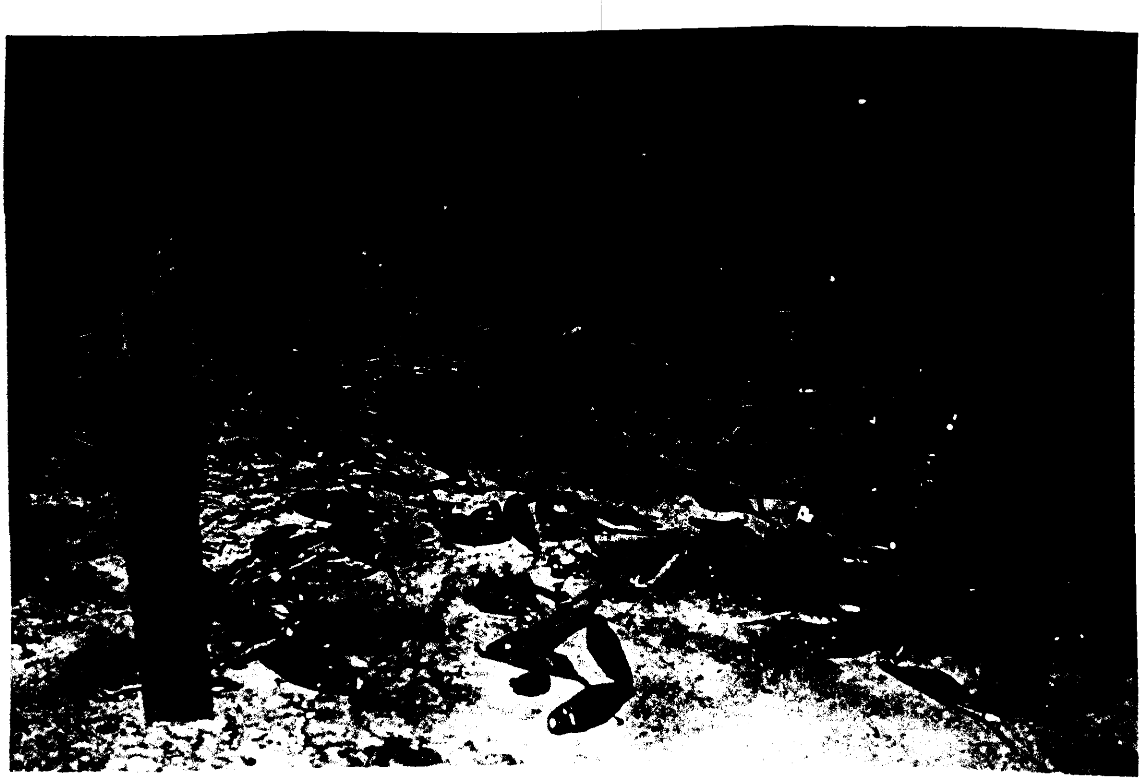

Table 1. PERCENTAGE AND TIME OF EMERGENCE ACCORDING TO SEEDING CONDITIONS FOR cv BUKETEN IN EXTREMADURA (RODRIGUEZ Y AYUSO, 1988).

LIGHT SOIL								
SEEDING DATE			SEEDING DEPTH			NUMBER SEEDS/gr		
DATE	DAYS	%	(cm)	DAYS	%	TYPE	DAYS	%
28-V	14,05	79,17	3	20,55	79,67	145	22,52	72,63
21-IV	25,05	71,00	4	21,77	78,00	128	23,44	72,19
12-V	25.27	64,92	2	23,66	67,75	122	23,29	55,71
30-III	27,95	51,92	1	26,32	41,58			
HEAVY SOIL								
6-V	21,93	54,42	4	38,88	64,00	128	39,44	55,00
22-III	56,41	52,25	3	38,80	58,00	122	38,97	53,38
			2	38,94	53,50	145	39,10	53,13
			1	40,06	39,83			

Table 2. COMPARISON OF INSERTION HEIGHT, FRUIT NUMBER AND FRUIT WEIGHT AT DIFERENT HEIGHTS FOR BUKETEN

Nº DI-FERENTS HEIGHTS	%		MAX. Nº FRUITS & HEIGHT (cm)				WEIGHT(gr)	
	20 cm	40 cm	Nº (20 cm)	H	Nº (40 cm)	H	20 cm	40
1	36,5	47	8,5	26,7	9,3	23,8	83,6	83,0
2	36,5	33	7,1	25,7	8,6	23,5	66,5	75,6
3	17,1	13	6,1	25,8	7,1	22,1	71,6	41,0
4	10,1	7	6,6	31,1	9,1	22,5	60,1	103,0

1: PLANTS WITH ONLY ONE FRUIT INSERTION LEVEL
2, 3, 4: PLANTS WITH TWO, THREE OR FOUR INSERTION LEVELS
"20 cm", "40 cm": DISTANCE BETWEEN PLANTING ROWS

Table 3. HARVESTING LOSSES (cv. BUKETEN)					
MACHINE.	DIST. (cm)	HARVESTED (%)	SOIL	PLANT	CLEANING SYSTEM
1	40	65,8	23,3	10,9	--
	20	80,1	13,2	6,8	-
2	40	80,1	17,1	3,1	-
	20	59,1	28,2	9,1	3

Table 4. FINAL HARVESTED PRODUCT(cv. BUKETEN)					
MACHINE (PLANT. DIST.)	% HARVESTED FRUIT				% TRASH
	TOTAL	RED	GREEN	BREAK	
1 (40)	88,3	83,1	5,2	0,0	11,7
2 (40)	67,6	55,4	7,6	4,5	32,4
2 (20)	72,4	66,9	3,9	1,5	27,6

Table 5. MACHINE CAPACITIES (cv. BUKETEN)						
MAC.	(*) PROD. kg/ha	SPEED km/h	FIELD CAPACITY (ha/h)	YIELD		MATERIAL CAPACITY (t/h)
				(t/ha)	(%)	
1	8500	1,65	0,198	5,6	65,8	1,11
2	8500	1,71	0,034	6,8	80,1	0,23
2	14000	1,85	0,037	8,3	59,1	0,31

(*) ACTUAL PRODUCTION IN THE FIELD

Table 6. HARVESTING LOSSES (cv. OCAL)					
MACHINE	VEL. km/h	HARVESTED (%)	% LOSSES		
			SOIL	PLANT	CLEANING SYS.
2	1,2	76,0	22	2	-
	2,0	69,0	20	11	-

Table 7. FINAL HARVESTED PRODUCT (cv. OCAL)					
MACHINE (PLANT. DIST.)	% HARVESTED FRUIT				
	TOTAL	RED	GREEN	BREAK	% TRASH
2 (1,2)	91,3	69,6	3,0	18,7	8,7
2 (2,0)	90,5	67,0	6.5	16,8	9,5

Table 8. MACHINE CAPACITIES (cv. OCAL)						
MAC.	(*) PROD. kg/ha	SPEED km/h	FIELD CAPACITY (ha/h)	YIELD		MATERIAL CAPACITY (t/h)
				(t/ha)	(%)	
2	12000	1,20	0,070	9,12	76,0	0,64
2	12000	2,05	0,100	8,28	69,0	0,83

(*) ACTUAL PRODUCTION IN THE FIELD