

# Developing of a Prototype to adapt Class Maize Chopper to Poplar Harvesting

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## ABSTRACT

The research activities conducted within the wooden cellulosic bio-masses storage tests showed that the reduced size of the chopped product has negative repercussions on the preservation of the stored product, the improving of the machine productivity in the harvest phase, and, in particular, on the evaluation of SRF harvesting mechanization systems, and highlighted some operative limits due to the cutting system of maize chopper Class Jaguar. The CRA-ING, in order to get over the above mentioned limits, designed a new cutting system. The new rotor was mounted on a Claas Jaguar 890 operating machine, replacing the commercial one and some experimental tests on second-cut poplar plantations harvest were executed. To this end CRA-ING designed a rotor of five series of double staggered knives for an amount of ten knives (the current one was made up of 12 knives - two sets of six). The new rotor developed for the poplar cutting improves the chopped product and the productivity of the machine. The experiments conducted in the last years demonstrated that in order to have a good air circulation in the pile, it has to be made up of thin chip (<12,5 mm), decreasing the moisture content and fermentative phenomena. The comparison of the results obtained in the different experimental tests, related to the same type of installation revealed an increase of 22% of the working capacity of the maize chopper machine equipped with the new rotor, with positive repercussions on the harvest costs related to the unit of surface (-19%). The new rotor (10 knives) shows a good performance in less consumptions, less power input (15%) and a greater speed of the advancing machine in the harvest phase, as well as a better chip size.

**Keywords:** Poplar harvesting, preservation, maize chopper, Italy.

## 1. INTRODUCTION

The research activities carried out on the lignocellulosic biomasses, in particular those dedicated to SRF harvesting mechanization, have underscored some operative limits of the maize chopper Class Jaguar 890 mainly due to the chipping device.

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Data analysis in the tests previously conducted (Pari *et al.*, 2008, Pari *et al.*, 2009) as well as the research activities on storage of poplar chips (1, 4, 5), have highlighted two negative aspects: 1) the reduced size of the harvested product, with negative repercussions upon preservation; 2) further improvement of the machine productivity during harvesting.

In order to overcome the limitations described above, CRA-ING has designed and charged the construction to the company “Biomasse Europe” of a new chipping device to be mounted on Class Jaguar 890 in place of that commercial one. Following to this, some experimental tests harvesting were carried out during R4S2 ( Roots 4 years and Stalks 2 years) poplar harvesting.

## 2. MATERIALS

### 2.1 The Harvesting Machine

The developing of a new prototype needs some experimental phases comprising: 1) experimental tests to evaluate the efficiency of the mechanical modifications, 2) a long testing period necessary to better evaluate the machine’s functional aspects as well as to determine which components can be stressed by an excessive wear and tear, 3) final evaluations of machine performance, including quality of the work and harvesting costs.

The preliminary experiments were conducted in April 2008 in the province of Pordenone; the experiments focused on the “Pegaso” poplar variety at second felling (Fig. 1).



Figure 1. Four years roots year and two years stalks planting with single rows of “Pegaso” variety

Due to the necessity of testing the prototype before growing season, together with the heavy rain at the end of winter 2008, we were forced to select a skeleton plot that although appeared not to be in good condition, allowed the experimental proof to go on. The unit worked even after rainy periods cutting and chipping of 20 rows, which averaged 241.40 m in length, on a net area of 1,41 ha.

Results from the preliminary experiments already indicated good prototype performance, confirming the success of both the prototype and the technical aspects developed.

In the subsequent phase, conducted through the collaboration with “Veneta Mais”, the machine harvested about 100 ha of poplar plantation, extending over several provinces in northern Italy (winter 2008-2009). A portion of the chipped product was used in the preparation of one of the

six piles, built, through the collaboration of Enervision Company, in Dosolo (in the province of Mantova) for the evaluation of different SRF storage methods in relation to energy content preservation, within the scope of the “Bio-energy” project begun in 2006. These research results have resulted in multiple scientific publications (Jirjis *et al.*, 2008, Pari *et al.* 2008, Pari *et al.*, 2008). It is, today, under evaluation the study on dry matter loss during the storage of two uncovered piles. One of the two piles was built by Class Jaguar equipped with CRA-ING rotor, the other one by the same machine but equipped with traditional rotor.

For the final valuations of the machine performance, including quality of the work and harvesting costs, some experiments were conducted in February 2009, near the Manfrin Farm at Candiana, in the province of Padova. These experiments were conducted on a planting at second felling (R4S2) with different poplar varieties.

The poplar SRF harvesting chain comprises a maize chopper Class Jaguar 890 of 372 kW equipped with CRA-ING rotor and a GBE-1 header (Fig. 2) for SRF harvesting and four farm tractors towing four carts with tipping body.



Figure 2. Class Jaguar 890 equipped with CRA-ING rotor during poplar harvesting

Similar to previous experiments conducted on planting at the second felling, the header was provided with beater structure that separates the rows aimed at separating the epigeal biomass, directing part of the fall of them towards the right inter-rows and the rest to the left inter-rows.

### 2.1.1 CRA-ING Rotor

The innovative CRA-ING rotor was designed to increase the dimensions of the harvested chips and to improve harvester performances. Analysis of the wood chips harvested with a traditional rotor showed that the small size of chips resulted from chip-crushing at the knife holder impact rather than only at the knives.

The new rotor (Figure 3), with ten fix knives (Figure 4), was made up of a steel drum (diameter=403 mm, length=670 mm and a holder with the capacity for 10 knives (five for part, equally distributed on the drum mantle) in order to allow the correct positioning of the knife holder for the subsequent welding stage. The knife holder was fixed with an inclination angle of 5° with respect to the straight lines of the rotor; the drum weight was 145 kg.

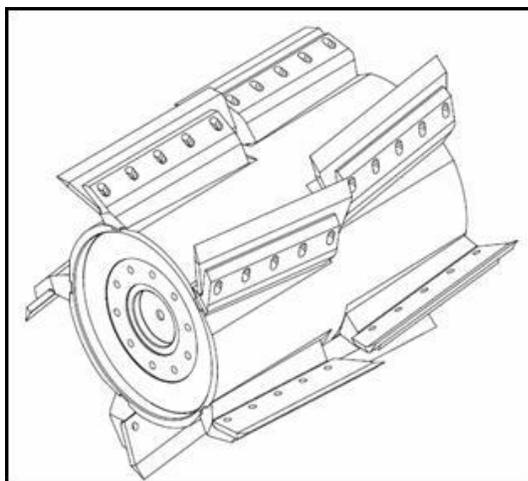


Figure 3. CRA-ING rotor mounted on Class Jaguar 890



Figure 4. Ten fix knives as well slots to better fix the position on the knife holder are distinctly visible in the CRA-ING rotor

Each knife holder (length=320 mm) was equipped with five slots in order to better fix and adjust the knife position. The knife has a maximum length of 380 mm, with a cutting angle of  $32.5^\circ$  and a series of five threaded holes, allowing the knives to be fixed on the knife holder at the slots' height.

We also modified the insertion angle to fit the knife holder on the cylinder/roll.

### 2.1.2 Carts for Carriage of Wood chips to the Storage centre

The units used for transporting the harvested product during tests were made using a Same Iron 120 93 kW tractor towing Vaia NL 14 II with a  $24 \text{ m}^3$  cart; the Class Ares 656 RC of 96.50 kW tractor towing Vaia NL 140-14T Export with a  $21 \text{ m}^3$  cart; the Same Supertitan 139 kW tractor towing Zaccaria ZAM 200 DMPP of  $25 \text{ m}^3$  cart; and a Fendt 412 mod. VARIO TMS of 91 kW, towing a Vaia NL 140-14T of  $20 \text{ m}^3$  cart. The storage center was 2000 m from the field.

## 2.2 Fields

The planting comprised different poplar varieties. March 2005 marked the fourth year of

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growing, with only one harvest two years before. The rectangular-shaped and level field, took up a gross area of 1.60 ha.

The carried out surveys emphasized an effective distance between the rows and on the row of 3 m and 0.53 m, respectively, for an investment of 6295 plants/ha.

### 3. RESULTS

#### 3.1 Morphological and Productive Characteristics of the Poplar Crop

The poplar crop had undergone a previous felling, and the average number of stalks for tree stumps with height  $\geq 1.5$  m was 2.50, with one prevailing stalk. The height and the average diameter of the main stalks were 8,24 m (std. dev.  $\pm 0.74$  m) and 73,89 mm (std. dev.  $\pm 22.15$  mm), respectively. For stalks with smaller dimensions, the height and average diameter were 5.23 m (std. dev.  $\pm 1.95$  m) and 36.70 mm (std. dev.  $\pm 16,10$  mm). The maximum sprout diameter observed in the planting was 147 mm.

#### 3.2 Working Times

The aim of the work was to evaluate the performance of the machine equipped with the innovative CRA-ING rotor. To this purpose, the standard harvesting times were worked out. The times mentioned above were categorized as a effective time (80.66%) and accessory time (19.34%). Rest times and maintenance times were not reported. The accessory times allotted time for turns (14,92%), due, in part, to the waiting time prior to trailer-towing tractor's completion of the turn, and for dead times (4,42%) due to alternation among tractors loaded with chip and those without any loaded. The machine worked at a speed of 1.46 m/s (5,25 km/h) and so doing attained an operative capacity of 1.51 ha/h.

The harvested product was 76 t/ha, and the operative productivity was 120,29 t/h.

#### 3.3 Product Losses

The overall losses registered were 0,49 t/ha, of which smaller branches and cut stalks that were not harvested represented 0.183 t/ha, main stalks represented 0.010 t/ha and product chipped, harvested, and lost during unloading on the harvested cart, represented 0,207. The total losses resulted to be 0.94 % of the harvested. The total production to harvest including the lost product was 76,49 t/ha (38,24 t/ha/year), equivalent to 30,56 t/ha of dry product (15,28 t dry substance/ha/year).

#### 3.4 Quality of the work

With regard to cutting quality, 1,17% of the stumps tested displayed slight damage with vertical cracks, and 0,54% had serious entity problems; of the remaining cuttings, 1,08% had important cracks. Some fringes of little importance were carried out on 0,45% of the stumps. Among all stumps, 96,76% did not suffered any kind of damage. Average cutting height was 106 mm (std. dev.  $\pm 33,91$ mm).

Within the damages due to the machine passage on the field, it were noticed furrows of the

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average depth of lower than 60 mm.

### 3.5 Granulometry

The comparative proof analyzed 40 surveyed chip samples (20 samples from the commercial rotor and 20 from CRA-ING rotor), each of them of the weight of 10 kg, on first (R2S2) or second-cut (R4S4) plantings. According to the proof results, the chip size distribution, derived from CRA-ING rotor, into granulometric classes vary, if we compare the two rotor production (Table 1 – Fig. 5 a, b).

Table 1. chip distribution into granulometric classes from current and CRA-ING rotor

Granulometric classes	Claas rotor R2S2	CRA-ING rotor R2S2	Class rotor R4S2	CRA-ING rotor R4S2
>125 mm	1,33%	0,55%	0,22%	0,16%
>100 mm	0,00%	0,00%	0,00%	0,00%
50-100 mm	0,00%	0,00%	0,00%	0,00%
25-50 mm	6,13%	23,88%	4,05%	3,14%
12,5-25 mm	43,92%	57,74%	42,98%	55,12%
6,3-12,5 mm	31,67%	13,95%	35,28%	31,18%
3,15-6,3 mm	7,06%	2,51%	10,10%	7,23%
<3,15 mm	6,44%	1,24%	7,31%	3,17%
Contaminants	3,45%	0,04%	0,06%	0,00%
Volumic mass (kg/m <sup>3</sup> )	297 (±13)	302 (±15)	274 (±12,42)	281 (±14)
Moisture of reference	61,6	61,0	60,4	60,0



Figure 5a. Chip produced by CRA-ING rotor



Figure 5b. Comparison of the chip obtained by Class Jaguar equipped with CRA-ING (a) and current rotor (b)

In the 12,5 – 25 mm class, one of the classes (including large chip size), was found to increase the first- and the second-cut values by +13, 82% and +12, 14%, respectively. In contrast, in the three 6.3 – 12 mm, 3,15 – 6,3 mm and < 3,5 m classes, we observed reduced values of -17,72%, -4,55 % and -5,20% for R2S2 and -4,10%, -2,87 % and -4,14 % for R4F2 (Fig. 6 – Table 2).

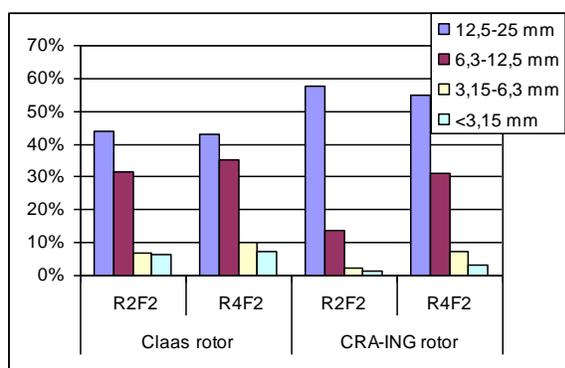


Figure 6. Distribution of the chip derived from CRA-ING and current rotor

Table 2. Distribution of the chip derived from CRA-ING and current rotor into the most represented granulometric classes

Granulometric classes	Claas rotor		CRA-ING rotor	
	R2S2	R2S2	R4S2	R4S2
12,5-25 mm	43,92%	57,74%	55,12%	42,98%
6,3-12,5 mm	31,67%	13,95%	31,18%	35,28%
3,15-6,3 mm	7,06%	2,51%	7,23%	10,10%
<3,15 mm	6,44%	1,24%	3,17%	7,31%

Results from the previous year's storage experiments (5), for which these data resulted very important, indicated that a pile was composed of a low percentage (<12,5 mm) of thin chips and by a greater percentage (12.5 – 25 mm) of granulometric fragments. This pattern guarantees good pile air circulation, improving moisture content and the control on fermentative

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phenomena.

We did not observe remarkable differences in the values of volume mass unit values from the chip derived from the two rotors chip at the same felling: 297 and 302 kg/m<sup>3</sup> for CRA-ING rotor and Class rotor on R2S2 respectively; 274 and 281 kg/m<sup>3</sup> for CRA-ING rotor and Class rotor on R2S2 respectively.

### 3.6 Operating costs

As regard the only mowing chipping machine provided with header, the operating costs were 180,89 €/h, corresponding to 119.79 €/ha and 1,50 €/t of the harvested. The operating cost for the whole unit resulted to be 288,72 €/h, 191,21 €/ha and 2,40 €/t of the harvested product.

## 4. COMPARISON OF THE TEST RESULTS

In the harvesting proof, the maize chopper, equipped with CRA-ING rotor, increased both working capacity and the hourly operative production, corresponding to the reduction of harvesting costs (Table 4).

The chipping device works at a speed of 1100 rpm. The new rotor, with 10 knives instead of 12 knives, makes about 1100 fewer cuts each minute, guaranteeing less consumption, less power input (15%) and greater speed for the advancing machine in the harvest phase, as well as a better chip size.

The planting which the Class Jaguar 890 worked on presented a similar productivity, 79 t/ha for current rotor and 76 t/ha for CRA-ING rotor. The comparison of the two tests results show a 33% increase of the effective speed of the machine during the harvest phase. In all, the machine equipped with CRA-ING rotor shows a 22% increase of the working capacity and the hourly operative production, with a reduction of the harvesting costs of 19% (Fig.7 – Table 3).

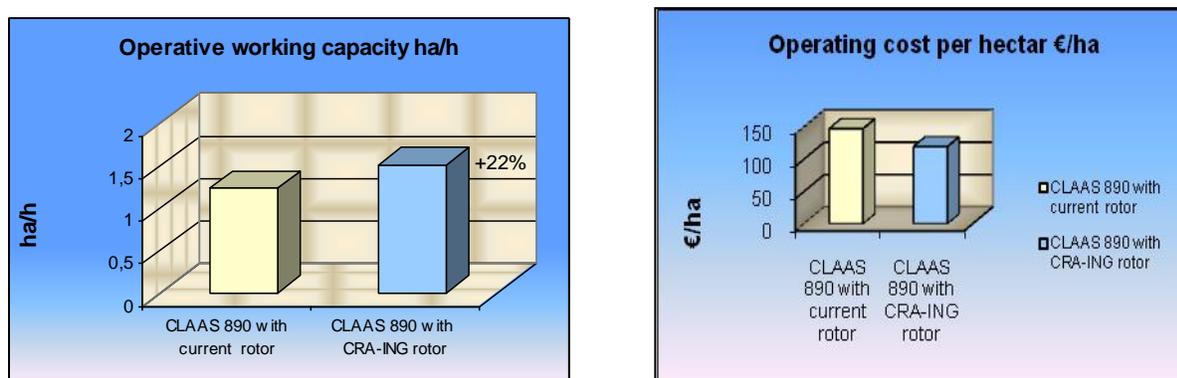


Figure 7. Class Jaguar equipped with current and rotor CRA-ING: operative working capacity and operating costs. Results obtained by harvesting simulation in the mentioned field

Table 3. Class Jaguar equipped with current and rotor CRA-ING: operative working capacity and operating costs

		Class 890 with current rotor	Class 890 with CRA-ING rotor
Operative working capacity	ha/h	1,239	1,515
Operating cost per ha	€/	147,06	119,4

Table 4. Results comparison of the two harvesting proof on planting at second felling by Class Jaguar 890 equipped with current and CRA-ING rotor

		CLAAS 890 with commercial rotor	CLAAS 890 with CRA-ING rotor
Cultivation typology		R4S2	R4S2
Performance of the machine			
Effective speed	m/s	1,64	2,18
Operative speed	m/s	1,20	1,46
Effective working capacity	ha/h	1,69	2,25
Operative working capacity	ha/h	1,23	1,51
Operative hourly production	t/h	98,42	120,29
Operating costs			
Hourly cost	€/h	180,89	180,89
Cost per ha	€/ha	147,06	119,79
Cost per ton of biomass	€/t	1,84	1,50

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## 5. CONCLUSIONS

From the comparison of the experimental proof, we estimate the increase in CRA-ING rotor working capacity to be 22% and the favorable impact on harvesting costs (-19%). The greater operative capacity is given by a high advancing speed of the machine equipped with an experimental rotor, during harvesting.

With regard to the size of the wood chips, the 12,5 – 25 mm class (one of the classes including large chip size) exhibited significant increases. In contrast, the < 12,5 mm class exhibited reduced values.

Although the good results of the innovative rotor, it is still under evaluation.

In fact, it was evaluated that the year increment is detached during poplar harvesting by CRA-ING rotor (Fig. 8), thus it was possible to increase only the length of the chip, limiting further developments.



Figure 8. Year increment of woody part detachment during poplar harvesting by CRA-ING rotor

At the moment specified activities aimed at the evaluation of separating the woody year increment into different species and into the same specie or variety in relation to the chipping system, is under developed in order to suggest further modifications on the rotor prototype particular attention is on the knives inclination degree.

## 6. REFERENCES

- Jirjis, R., Pari, L., Sissot, F. 2008. Storage of poplar wood chips in northern Italy, World Bioenergy 2008 Congress, 27-29 Maggio 2008 Jonkoping, Svezia
- Pari, L., Civitarese, V. 2008. Nuova testata di raccolta in prova su pioppo biennale. L'informatore Agrario n.° 35.
- Pari, L., Civitarese, V., Del Giudice, A. 2009. Valutazione di diversi modelli di Claas Jaguar in diverse condizioni operative. Speciale Informatore Agrario n 28/2009
- Pari, L., Fedrizzi, M., Ciriello, A. - SRF poplar chips stocking methods comparison to lessen fuel depletion from production to utilization 16th European Biomass Conference & Exhibition, 2-6 June Valencia
- Pari, L., Sissot, F., Ciriello, A. 2008. La migliore qualità del cippato si ottiene nel cumulo coperto. L'informatore Agrario n.° 39/2008.

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