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Research Paper

# Effect of short rotation coppice plantation on the performance and chips quality of a self-propelled harvester

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The performance of coppice harvesting machines is influenced by parameters such as field yield, the shape and size of the plantation and the space for turning at the headland. The quality of chips and the effect of the dendrometric characteristic of nine different species (*Fraxinus angustifolia, Robinia pseudoacacia, Salix alba, Eucalyptus occidentalis, Populus nigra L.* and four genotypes of *Populus x euroamericana* (Grimminge, Hoogvorst, Muur, Vesten) grown in the same flat plot of about 4.5 ha on the performance rate and quality of the work, was evaluated. Field yields ranged from 33 t $ha^{-1}$ to ~95 t $ha^{-1}$, for the *S. alba* and *E. occidentalis*, respectively. The harvester worked with an average speed of 0.91 m $s^{-1}$ (±0.22) and average productivities of 0.98 ha $h^{-1}$ (±0.24) and 45.25 t $h^{-1}$ (±5.56). There was a satisfactory linear correlation between the working speed of the machine and field yield. The quality of the chips showed some variability with values of moisture content ranging between 42.7% and 57.3% (for *R. pseudoacacia and S. Alba* respectively) and values of bulk density from 273 kg $m^{-3}$ to 313 kg $m^{-3}$ (for *Populus euroamericana* Vesten and *E. occidentalis* respectively).


## 1. Introduction

The aims of the European Union are to reduce 2020 greenhouse gas emissions to 80% of their 1990 emissions and to replace 20% of its final energy needs from renewable sources (Tol, 2012). This has led leading to an increasing interest in woody biomass for the production of biofuels, biochemicals, heat and electricity (Klass, 1998; Parikka, 2004; Van der Stelt, Gerhauser, Kiel, & Ptasinski, 2011; Zhu & Pan, 2010). Quaak, Knoef, and Stassen (1999) and McKendry (2002) affirmed that biomass represented a more sophisticated form of solar energy accumulation and it can be seen as a possible substitute to fossil fuels (Okello, Pindozzi, Faugno, & Boccia, 2013).

Rapidly growing trees are one of the most promising alternatives for the production of biomass when planted in a

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**Nomenclature**

| | |
|---|---|
| $\overline{M}$ | Mean of measured data, m $s^{-1}$ |
| Adjusted $R^2$ | Adjusted coefficient of determination, dimensionless |
| $D$ | Difference between simulated and measured value, m $s^{-1}$ |
| $EF$ | Efficiencies index, dimensionless |
| $M$ | Measured value, m $s^{-1}$ |
| MANOVA | Multivariate analysis of variance |
| $n$ | Number of observations |
| odt | oven dry tons |
| OLS | Ordinary Least Squares |
| p(t) | Level of significance, dimensionless |
| S | Simulated value, m $s^{-1}$ |
| SRC | Short rotation coppice |
| SRF | Short rotation forestry |
| x | Field yield in tons of fresh biomass per hectare, t $ha^{-1}$ |
| y | Work speed, m $s^{-1}$ |
| *Subscripts* | |
| $i$ | ith observation |

short rotation coppice (SRC) regime (Broeckx, Verlinden, Vangronsveld, & Ceulemans, 2012). Compared to other sources, dedicated crops show the highest yield in the shortest growing time (Alig, Adams, McCarl, & Ince, 2000). During the last ten years short rotation coppice has become more and more common in Italy with more than 4000 ha under cultivation, mostly located in the North of Italy (Spinelli, Nati, & Magagnotti, 2009), while the central and southern regions are cropped with small plots (Di Matteo, Sperandio, & Verani, 2012). Field yield of SRC plantations depends on the species considered, the genotype and on the characteristics of the sites. Genetic improvement programs within the EU have produced clones with high production rates for a wide range of climates and sites (Deckmyn, Muys, Garcia Quijano, Ceulemans, 2004; Liberloo, Calfapietra, Lukac, Godbold, Luos, et al., 2006). Species used include *Salix Alba*, *Fraxinus augustifolia*, *Eucalyptus occidentalis*, *Robinia pseudoacacia*, *Populus nigra*. The biomass produced by these energy crops are of low value and it is therefore necessary to obtain high yields (Verlinden, Broeckx, Van den Bulcke, Van Acker, & Ceulemans, 2013). Poplar (*Polulus* sp.) are one of the more suitable biomass crops for SRC in temperate regions (Bradshaw, Ceulemans, Davis, & Stettler, 2000) and many studies have shown that the annual yields between 3 and 20 t [dry matter] $ha^{-1}$ (Ceulemans &Deraedt, 1999; Dillen, Marron, Bastien, Ricciotti, Salani, et al., 2007; Facciotto & Lioia, 2005; Mareschi, Paris, Sabatti, Nardin, Giovanardi, et al., 2005). Two different harvesting methods are generally used: *one phase*, with cutting and chipping simultaneously (Spinelli et al.,2009), operated with self-propelled chipper, and *two phases*, with cutting is done in winter, drying in the field and chipping in the following June (Pari et al., 2013). In order to make the SRF more profitable, and ensure sustainable cultivation, harvesting must be realised at high operational efficiency.

Field yield is one of the crop main variables to be taken into account when assessing the performance of a harvester (Handler & Blumauer, 2011), but other parameters can affect the machine performance such as the slope of the plot, shape and size of the plantation, the available space for turning in the headland, the bearing capacity of the soil at the harvesting time, machine power applied, trailer capacity and the experience of the staff and the methods used. For these reasons it is difficult to establish a direct relationship between work speed and field yield, unless comparative tests are conducted under similar operating conditions.

Harvesting tests of nine different species that grown as SRC, within a single flat area of about 4.5 ha were organised in April, 2013, at the experimental farm of Campania region “Improsta”, Italy. Harvesting was carried out over a single day using the same professional operators and machines in order to establish as similar as possible conditions for the duration of the test. The aim was to identify a correlation between the working speed of the harvester and the field yield of the different species of plantations, using data collected under similar conditions. The quality of the work done by the machine was also assessed as well as the quality of the chips obtained from different species by the same device.

## 2. Materials and methods

### 2.1. *Site description and plantation layout*

The SRC plantation was located in the Salerno province, Italy (40°33′32.18″N; 14°58′15.6″E) and consisted of different species and varieties that were planted in 2007 using both bare-root seedlings and cuttings (density of 6666 plants $ha^{-1}$). The crops harvested were: *Fraxinus angustifolia, Robinia pseudoacacia, Salix alba, E. occidentalis, P. nigra L.* and four genotypes of *Populus x euroamericana* (Grimminge, Hoogvorst, Muur, Vesten). The trees, first coppiced in 2010, were in their second three-year cutting cycle (roots were aged 6 yr and stems aged 3 yr R6S3). The total area harvested was ~4.50 ha but, in order to compare the performance of the harvesting machine, data collection (dendrometric surveys, working time measurements, etc.) was made on nine plots, one for each treatment, with a unit surface area of 840 $m^2$.

Before starting the tests, the effective density, the average number of shoots per plants, the height and the diameter of the main and secondary stems were measured at 100 mm from the ground, on 10 randomly chosen plants per plot. The total amount of biomass produced by each treatment was evaluated by weighing, on a certified scales, and the wood chips were blown into a trailer on each experimental plot.

### 2.2. *Data collection*

The machinery used for the trials were a Claas Jaguar self-propelled chipper 880 (nominal power of 370 kW), equipped with GBE-1 head, (Spinelli, Nati, & Magagnotti, 2008; Spinelli et al. 2009) and a Massey Ferguson 6497 Dyna-6 tractor (nominal power of 160 kW) coupled to a Zaccaria trailer with a capacity of 40 $m^3$. The drum chipper worked using only 12 of the 24 knives available, in order to avoid production of