CAMELINA SEEDS HARVESTING: EVALUATION OF WORK PERFORMANCE OF A COMBINE HARVESTER IN TWO EXPERIMENTAL FIELDS IN ITALY AND SPAIN

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ABSTRACT: *Camelina sativa* (L.) Crantz in an interesting oil crop for multipurpose uses and its cultivation is gaining growing attention in Mediterranean context. This species is indeed suitable for cultivation in marginal lands and feasible to crop rotation with cereals. Camelina seeds are currently harvested by a combine harvester equipped with cereal header. Considering the tiny dimension of the seeds, which can lead to substantial seed loss, proper assessment of mechanical harvesting is a key issue for the correct development of effective camelina seeds supply chain. The present study is one of the first which aimed to analyze mechanical harvesting of camelina seeds through combine harvester. Work performance, in details work productivity, harvesting costs and seed loss, of harvesting operation were carried out in two experimental field tests. The first one located in Northern Italy and characterized by organic farming, whilst the second experimental field was located in Spain, with conventional farming system. While working productivity and harvesting costs resulted to be comparable to the ones found in literature for other seeds collected by combine harvester, seed loss showed higher values. This is mainly related to two factors: the small dimension of seeds and the presence of weeds. Proper combine setting and assessment of the working speed seem currently being the most effective solutions to reduce seed loss.
Keywords: bioenergy; oil crops; work performance; harvesting loss

1 INTRODUCTION

One of the most ambitious goals of European Community consists of increasing renewable energy production [1]. Agriculture sector can play a key role in reaching such aim. Indeed, agriculture can contribute to bioenergy production both with residues [2,3] and with dedicated crops [4]. In particular, biodiesel production from oil crops represents an interesting approach to tackle this issue [5,6]. On the other hand, cost effectiveness of biodiesel production from dedicated oilseed crops is still a major concern [7]. Moreover, a crucial aspect in non-food crops cultivation consists of avoiding competition with food crops [8]. Taking into consideration these aspects, *Camelina sativa* L. represents an interesting species. Indeed, camelina oil can be used for several application [9–11], including biodiesel and jet-fuel production [12–14] and it is able to grow in marginal lands [15]. Finally, camelina is highly suitable for rotation with several cereals [16,17]. However, proper studies dealing with cost of harvesting and logistic of camelina crop are still lacking. In particular, camelina harvesting is a challenging issue, considering the tiny dimension of the seeds, which can lead to problems in the collection through combine harvester [18].

Considering what previously reported, this study represents one of the first evaluation of camelina seeds collection via combine harvester in two different study areas in Italy and Spain. In particular authors analyzed field capacity, harvesting costs and seed loss.

2 MATERIALS AND METHODS

2.1 Study areas

Two different experimental fields were used for field surveys. The first one in Northern Italy and the second one in Northern Spain (Figure 1).

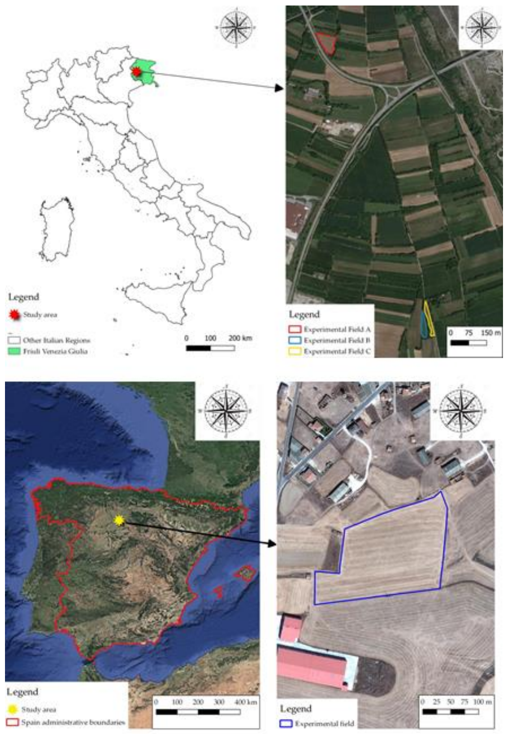

Figure 1: Maps of the experimental fields in Italy and Spain.

The Italian experimental field was cultivated in organic farming while the Spanish one was grown under conventional farming regime.

2.2 Pre-harvest tests

In both the experimental field, prior to harvesting operation, 10 square sample plots of 1 m^2 each were randomly identified within the field surface to assess the whole aerial biomass (for camelina: straw, siliques, and seeds). Plants were cut at base level, counted and measured in weight and height. Siliques and seeds were removed manually and weighed separately. Subsequently, siliques, seeds and a representative sample of straw form the various sample plots were collected in plastic sealed bags and shipped to the laboratory of Research Centre for Engineering and Agro-Food Processing (CREA-IT) for further measurements. In particular, theoretical yield of seed, dry weight (DW), bulk density and moisture content.

2.3 Machineries used for seeds collection

Two different combine harvesters equipped with cereal header were used for harvesting. Details of the machineries are given in Table I.

Table I: Details of the combine harvesters in the two experimental fields.

Parameter	Italy	Spain
Combine Harvester Model	Claas Lexion 530	John Deere W650
Cereal header model	Cressoni CRX	John Deere
Type of cleaning shoe	Conventional	Conventional
Header width (m)	6	6.7
Rotor speed (rpm)	600	800
Cleaning Fan Speed (rpm)	700	700
Openings of Upper Sieve (mm)	minimum	Closed
Openings of Lower Sieve (mm)	minimum	5
Straw treatment	threshed	threshed

2.4 Work productivity and costs

Work performance were assessed in terms of effective field capacity (EFC, ha h^{-1}) after recording of the working times according to the methodology proposed by Reith et al. [19]. Data regarding working performance were used as input for the calculation of the harvesting costs, according to [20].

2.5 Seed loss evaluation

Analysis was focused on seed loss due to inefficiency of the cleaning shoe of the combine harvester. Seed loss was therefore evaluated according to the methodology proposed by Stefanoni et al. [21] and Latterini et al. [22]. In details a plastic tarpaulin was installed rear the combine harvester in order to collect the seeds lost from the sieves and straw walkers. The expelled biomass was collected thanks to the tarpaulin and shipped was shipped to the laboratory, then weighted and sieved for assessing the amount of seeds lost.

3 RESULTS AND DISCUSSIONS

3.1 Biomass assessment

Results of biomass characterization in the two experimental fields are given in **Table II**.

Table II: Biomass characterization.

Parameter	Italy	Spain
Straw (Mg_{fm} ha^{-1})	1.65	3.31
Siliques (Mg_{fm} ha^{-1})	0.40	1.20
Seeds (Mg_{fm} ha^{-1})	0.86	1.03
Seeds bulk density (Mg m-$^{3)}$	0.61	0.64
Plant density (N m^{-2})	114	311
1000-seeds weight (g_{fm})	1.76	1.19

Interestingly, the substantially higher plants' density in Spanish field led to higher biomass of straw and siliques, while instead the difference in terms of seed yield is present but not so marked. Focusing on seed yield, the reported values in both the experimental fields are in line with previous literature findings regarding camelina cropping in Mediterranean areas [17,23].
Data regarding work performance and costs assessment are instead given in Table III.

Table III: Work performance and costs.

Parameter	Italy	Spain
EFC (ha h^{-1})	1.22	3.17
Seed yield (Mg ha^{-1})	0.84	0.95
Seed loss (%)	2.0	5.8
Costs per surface unit (€ ha^{-1})	164.71	65.97
Costs per biomass unit (€ Mg^{-1})	195.43	69.42

As it is possible to notice there is a marked difference between the EFC in the two experimental fields. Such difference is mostly related to the shape of the fields. In Spain the shape of the field was rather regular with wide headlands which allowed for rapid turning time, thus increasing EFC. Instead in Italy the shape of the field was irregular with limited space for turning. Therefore, in this case EFC resulted substantially lower. As a consequence also harvesting costs resulted much higher in Italy than in Spain. On the other hand, seed loss was lower in Italian field than in Spanish one. This is mostly related to the lower density of plants in Italian field (Table II), which resulted in a lower amount of biomass which entered the cleaning system of the combine harvester in the time unit. Moreover, the presence of weeds which characterized the Spanish case-study also contributed to increase the amount of lost seeds.

Previous studies reported seed loss in camelina mechanical harvesting comparable to the values found in Spanish experimental field [18,24], while instead seed loss amount in Italy was, until now, the lowest reported in dedicated scientific tests, and more similar to other oilseeds like sunflower, canola and safflower [4,25–28]. Focusing on comparisons with previous similar studies about mechanical harvesting of camelina through combine harvester, unit harvesting costs resulted comparable to literature one for Spain field, whilst substantially higher regarding Italian one. In particular, Stefanoni et al. reported 48.51 € ha^{-1} [24], while Stolarski et al. found 46.70 € ha^{-1} [29]. Therefore, in both cases, lower, but comparable ,to the values found in Spain case-study; while much lower than in Italian one. However, it is important to highlight that Italian case-study was a first attempt of camelina cropping, so with low surface with an experimental approach. Thus, valued found in Spain represent in a clearer way a typical situation of camelina seed harvesting in Mediterranean area.

4 CONCLUSIONS

Camelina cropping in Mediterranean area is interesting under several points of view, considering the multiple uses of the oil of this species and its suitability for rotation with cereals cropping. Mechanical harvesting is currently performed through combine harvester, with harvesting costs comparable to other species whose seeds are collected through the same machinery. However, regarding camelina, the tiny dimension of seeds and the presence of weeds generally lead to higher seed loss than other oilseeds species. The findings of the present study confirmed this assertion, reporting seed loss higher than the usual one for sunflower or canola, mostly in the Spanish case-study. Proper combine setting and assessment of the working speed seem currently being the most effective solutions to reduce seed loss.

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