Industrial Crops and Products 68 (2015) 90–96

Contents lists available at ScienceDirect

Industrial Crops and Products

journal homepage: www.elsevier.com/locate/indcrop

Harvesting strategies of bast fiber crops in Europe and in China

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ARTICLE INFO

Article history:
Received 25 June 2014
Received in revised form 4 September 2014
Accepted 5 September 2014
Available online 1 October 2014

Keywords:
Bast fiber
Mechanization
Harvesting
Flax
Hemp
Kenaf

ABSTRACT

About two thousand species of plants are known in the world to yield natural fibers, but just a few are commercially important, providing nearly 90% of the global production of natural fibers.

Since ancient times, humans required fiber to produce cordage, tools, clothes, nets, etc., in order to provide food and shelter.

Among the most productive fiber plants, the bast fiber crops are undoubtedly considered as major contributors. The bast fibers are sclerenchyma fibers associated with the phloem of crops such as flax, hemp, kenaf, ramie, nettle, jute, etc.

Currently, in both Europe and China, bast fibers are used for industrial applications in textile, construction, automotive, and other industries. Recently, bast fibers gained importance also as a renewable feedstock for the production of strong, lightweight, composite materials.

However, there are factors in agro-industrial chain that limit the broad commercialization of these crops and their products. From an agronomical point of view, a part of the problems are associated with technological gaps in harvesting technologies, which impede the full exploitation of some crops. For instance, the production of high-quality fibers for textile firstly depends on the quality of the raw material, which in turn is linked, among the others, with the efficiency of the harvesting system adopted. In most cases, these systems were developed locally, based on available solutions in connection with specific local agricultural practice.

The aim of this paper is to present a review of the existing mechanical harvesting systems for bast fiber crops in Europe and China, with special reference to hemp, flax, and kenaf. In addition, the work will furnish a description of the innovations that have been adopted in recent years to improve the harvesting processes in order to increase the value of these crops and their products.

1. Introduction

In ancient times, plants were fundamental in satisfying man's necessities in respect of food, clothing, and shelter. Even if materials like animal skin and hides were also used to respond to the human needs, especially for clothing, they were insufficient for such a purpose. In that period, humans also required some form of cordage for creating rudimental tools, snares, nets, etc., in order to procure food and provide shelter. Therefore, flexible fibers obtained from stems, leaves, roots, etc., of various plants were used for the above purposes very well. Currently, about two thousand species of plants are known to produce natural fibers, but just a few are commercially important. These provide about 90% of the global production of natural fibers (Gowda, 2007).

A large part of the natural fiber comes from the bast fiber crops. The bast fibers are sclerenchyma fibers associated to the phloem of the plant. They arise with primary tissues from the apical meristem, or with secondary tissues produced by the lateral meristem, the cambium, associated with the vascular tissues of the stem (Müssig, 2010). Important bast fibers crops are flax, hemp, kenaf, ramie, jute, etc.

Currently, bast fibers find several applications in textile, construction, and automotive industries. Recently, bast fibers gained importance also as renewable feedstock for the production of strong, lightweight composite material, offering several advantages as replacement for fiber glass (Erwin and Seber, 1996; Lawrence et al., 2001). Nowadays, the application of natural fiber composites are found in automotive interiors, agricultural and automotive exterior panels, acoustic and thermal insulation, furniture, recreational sport products such as tennis racquets, skateboards, bike frames,

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http://dx.doi.org/10.1016/j.indcrop.2014.09.010
0926-6690/

Fig. 1. Claas Jaguar 830 with Kemper header (http://fibrafp7.net/portals/0/HempFlax,%20meeting%20Rome%2020-03-13.pdf).

Fig. 2. Blücherho 02 mounted on self-propelled New Holland 1905 (http://www.kranemann.org/fotogalleries/hanf/I%20Kranemann%20GmbH%20I/album/Fotogallerie.html).

marine products, and construction materials (Deyholos and Potter, 2014).

The extraction of the bast fiber from harvested stems usually involves a process called retting. The most common approach for most fiber crops is called "dew retting", in which harvested stems are left on the ground for several weeks to allow the microbial degradation of the pectin, a structural heteropolysaccharide that binds the fibers one to each other and to surrounding tissues. At the end of the process the fibers are easily separable during mechanical processing (Tabeco Tanner, 1922).

A crucial element in agricultural management of the bast fiber crops is the mechanical harvesting. In fact, in most cases, the harvesting systems for these crops are developed locally, based on available solutions in connection with specific local agricultural practice (Kaniewski, 2010). It implies the need to spread information about the available technology and mechanical innovations at national and international level.

This work consists of a review of the current mechanical harvesting systems applied to bast fiber crops in Europe and China, with special reference to hemp, flax, and kenaf. The aim of the paper is to furnish an overview of the possible solutions that exists in Europe and China for harvesting common bast fiber crop. In addition, the study will focus on analysis and description of innovations that have been recently applied in mechanical harvesting technology in order to improve the harvesting processes and to furnish high-quality fibers. Finally, mechanical solutions for combined harvesting (fiber and seeds) will be presented as well.

2. Mechanical harvesting systems for hemp in Europe

2.1. Whole stem harvesting

Usually, hemp for fiber production is harvested at full flowering of male plants. This period corresponds to the maximum yield of primary bast fiber (Amaducci et al., 2008; Mediavilla et al., 2001).

Hemp is different from most crops because of its considerable height (2–3 m and more), its thick and hard stems (Shafer and Henermeier, 2006), its relatively high-green mass yields (over 50 t/ha,) (Amaducci et al., 2008; Balodis et al., 2011), and content of fiber (5–6% of the green mass) (Berenji, 1996; Martinow, 1996; Kozłowski et al., 1998a,b; Grabowska et al., 1998; Lohmeyer, 2000).

In whole stem harvesting, the stems of the plant are maintained entire or in long sections for collection and processing. After mowing, the stalks are arranged parallel to one another in swaths on the ground or bounded and collected by hand for creating stem piles for air drying (United States Department of Agriculture, 2000). The material obtained in this type of harvesting consists of long fibers employable in textiles. However, mechanical harvesting systems capable to furnish processable material for scutching lines are still limited. This is because the transformation industries require stems portion no longer than 1 m. In fact, because of the inadequacy of the old hemp scutching lines present in Europe, the vegetable material is typically processed in flax lines, which work with stems, generally, no longer than 1 m (Sponner et al., 2005).

An example of machine used for the whole stem harvesting is the model ZK-1,9 (SEL'MASH, Bezheck, Russia). The base version of this machine was designed to cut and arrange the stems parallel to one another in ordered windrows. After the installation of a special conveyor, the machine was able to replace the operation that in the past was carried out by hand, i.e. cutting the plants and creating bundles which are left on the ground to be arranged successively by workers for drying (Kaniewski et al., 1997).

2.2. Cut stem harvesting

In this type of harvesting, the plants after mowing are sectioned or shredded and left disorderly on the soil by forming windrows or a uniform bed of mowed stems and leaves. In this case, the availability of machines is higher in respect to whole stem harvesting, but this plays against the quality of the fibers obtained after the extraction. In fact, the fibers obtained in this case are difficult to use in the textile industry (Müssig, 2010).

The first machine, which is also the most common in Europe, is the HempCut 3000/4500 (HempFlax, Oude Pekela, Netherland). The machine, initially called "HempFlax/HempCut 3000/4500", was further developed by the company Wittrock (Rhede, Germany), becoming the worldwide sold machine HempCut 3000 or 4500 according to the working width (Fig. 1).

The HempCut machine presents a modified head developed by the company Kemper (Stadtlohn, Germany) and an adapted one-knife cutting drum. During the machine progress the stalks of the plant are fed longitudinally into the chopping drum, cut into pieces of about 600–700 mm and left directly under the drum in a windrow (Mastel and Stolzenburg, 2002).

Another machine called "Bluecher 02/03" (Kranemann, Klocksin, Germany, Kranemann.org, 2014) was developed in late 1990s (Fig. 2).

The basic concept of this harvesting system was to preserve the original array of the hemp plant until it is cut into pieces of 600–700 mm. Initially, the conveyor elements maintain and collect hemp stalks in a vertical position. Successively, through cutting discs located at fixed positions on the drum, the stalks are sectioned