Study on Optimal Working Conditions for Picking Head of Self-Propelled Pepper Harvester by Factorial Test

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Abstract

Purpose: Pepper prices have risen continuously because of a decrease in cultivation area; therefore, mechanical harvesting systems for peppers should be developed to reduce cost, time, and labor during harvest. In this study, a screw type picking head for a self-propelled pepper harvester was developed, and the optimal working conditions were evaluated considering helix types, winding directions of helix, and rotational speeds of the helix. Methods: The screw type was selected for the picking head after analyzing previous studies, and the device consisted of helices and a feed chain mechanism for conveying pepper branches. A double helix and a triple helix were manufactured, and rotational speeds of 200, 300, and 400 rpm were tested. The device was controlled by a variable speed (VS) motor and an inverter. Both the forward and reverse directions were tested for the winding and rotating directions of the helix. An experiment crop (cultivar: Longgreenmat) was cultivated in a plastic greenhouse. The test results were analyzed using the SAS program with ANOVA to examine the relationship between each factor and the performance of the picking head. Results: The results of the double and triple helix tests in the reverse direction showed gross harvest efficiency levels of 60–95%, mechanical damage rates of 8–20%, and net marketable portion rates of 50–80%. The dividing ratio was highest at a rotational speed of 400 rpm. Gross harvest efficiency was influenced by the types of helix and rotational speed. Net marketable portion was influenced by rotational speed but not influenced by the type of helix. Mechanical damage was not influenced by the type of helix or rotational speed. Conclusions: Best gross harvest efficiency was obtained at a rotational speed of 400 rpm; however, operating the device at that speed resulted in vibration, which should be reduced.

Keywords: Factorial test, Pepper harvester, Picking head, Screw type, Working conditions

Introduction

Peppers contain a substance called capsaicin, producing mild to intense spice, and they are available in markets in fresh-green or red, dried, or powdered form. The cultivation area for peppers has decreased from 2010 to 2014, and the price of peppers has increased (KOSTAT, 2013). Harvest labor accounts for 32.2% of total labor when hand harvest is used (KOSTAT, 2014a), which requires 10 times higher costs than rice harvesting (KOSTAT, 2014b). For this reason, pepper production has decreased. The mechanization rate for upland farming is 42.7%, and 90% of that is for plowing, land preparation, and pest control. The mechanization rate for sowing, transplanting, and harvesting is only 10% (MIFAFF, 2010). Presently, the mechanization rate for the upland farming has increased by 56% fiducially in 2015 (Choi et al., 2015)

Mechanization for harvesting peppers reduced labor use by 51% and costs by 38% (Hong et al., 2006). The harvest cost for peppers decreased by 51% from 478,320 won to 232,890 won per 1,000 m² with the development of harvesting machines (Choi, 2006).

T Company, a domestic company, has been developing
self-propelled pepper harvesters which include picking heads, screening parts, conveying parts, and collecting parts to reduce labor and costs since 2014.

Many studies have been conducted in Korea to develop pepper harvesting machines, and companies from Israel and the USA have developed pepper harvesters (Paul et al., 2011; Wall et al., 2003).

Paul and Walker (2010) developed four types (Disk, Chain, Creager, and Hernandez) of attachable harvest machines by using the platform of cotton harvesters manufactured by John Deere. In addition, the helix type harvester, which was developed in Israel, was selected for this study. A total of five types of harvesters have been used in the field test. The helix type harvester with a double open-helix showed the best gross harvest efficiency and mechanical damage among the various harvesters.

Lee et al. (1994) designed a screw type harvester for factorial test and examined the four levels of rotational speed (110, 145, 180, and 215 rpm) and three levels of moving speed for the pepper plant (0.1, 0.2, and 0.3 m/s). The best performance was observed at the rotational speed of 180 rpm and moving speed of 0.1 m/s.

Developing pepper harvesters should consider domestic cultivar and cropping systems because these are different from foreign peppers.

Harvesting efficiency is important for the pepper harvester, and the dividing ratio of the picking head is the most important factor that influences the harvesting efficiency.

This study developed a screw type picking head to examine the following design factors: types, winding directions, and rotational speeds of the helix.

**Materials and Methods**

**Picking head**

The picking head developed in this study was composed of a conveying part with a feed chain mechanism and driving parts with helices. Each driving part had two 3.4-kW VS motors and an inverter to control the speed of the helix and the feed chain. Power was transmitted using the bevel gears to rotate each helix in different directions. A rail was installed at each end of a helix to adjust the angle of the helix. Figure 1 shows the conceptual diagram of the self-propelled pepper harvester. Figure 2 shows the experiment bench for the picking head used in this study. The type of helix (double helix or triple helix) was