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Biometric and engineering properties of garlic for mechanical harvesting

KHAMBE VISHAL K., DIPANKAR D.E.*, P.K. SAHOO AND S.K. JHA[1]
Division of Agricultural Engineering, Indian Agricultural Research Institute, New Delhi-12
dipankar52@gmail.com

ABSTRACT Design of crop production and processing equipment requires biometric and engineering properties of relevant crop. Garlic (*Allium sativum*) is the second most important bulbous crop from *Alliaceae* family after onion. Some biometric and engineering properties of garlic were evaluated as a function of moisture content. The number of leaves per plant at its harvesting stage ranged between 5 to 7 with modal value of 5 at all three levels of plant moisture content. Length of garlic plant and its weight decreased from 696 - 684 mm and 39.57 - 34.71 g, respectively, as the plant moisture content decreased from 42.38 - 36.21% (db). Polar diameter, equatorial diameter and shape factor of garlic bulb increased from 36.72 - 40.49 mm, 34.07 - 37.95 mm and 0.91 - 0.94, respectively, with same decrease in plant moisture content. Angle of rolling resistance increased from 22.64° - 35.64°, while crushing resistance and cutting resistance of garlic plant increased from 463.86 - 544.06 N and 218.40 - 268.60 N, respectively, with decrease of plant moisture content from 42.38 - 36.21% (db). These values are essential for design of mechanical harvester for garlic.

Keywords: Biometric, engineering, garlic, moisture content, mechanical harvester.

India is blessed with varied agro-climatic conditions, which make it possible to grow a wide variety of vegetable crops round the year. India has the distinction of growing the largest number of vegetable crops compared to any other country. Among these vegetables, garlic (*Allium sativum* L.) is one of the main bulbous crops from *Alliaceae* family after onion. It is native from central Asia and presently grown across most parts of the world. It has been cultivated for centuries all over the world on account of its culinary and medicinal properties [1]. India ranks second after China in world's garlic production with an annual production of about 1.06 Mt cultivated in 0.2 Mha [2]. Garlic bulbs are valued for their flavour and command an extensive commercial importance because of their medicinal value and application in food and pharmaceutical preparations. The use of garlic as condiment, garlic oil as insecticide, garlic paste as bio fungicide, garlic residue with antibacterial properties, garlic as medicine including use for cancer treatment and in human nutrition are now well recognized [2]. Despite its many uses, sufficient information on the biometric and engineering properties of garlic plant appears to be lacking. To design and develop any specific crop production and processing equipment, information/knowledge biometric and engineering properties of plant are essential.

Biometric and engineering properties of garlic plant like weight of plant, plant length, polar diameter, equatorial diameter of garlic bulb and angle of rolling resistance affects the design parameters of a machine. For this reason, the determination and considerations of these properties became very important.

In recent years, many researchers have investigated similar properties for various agricultural crops. The physical and mechanical properties of onion (*Allium cepa* L.) crop relevant to mechanical detopping were studied [3]. The engineering properties of turmeric rhizome as a function of moisture content were investigated [4]. The biometric

*Corresponding author
[1]Division of Post Harvest Technology, IARI, New Delhi-110012

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and mechanical properties of onion crop relevant to component designs of machine for its harvesting were studied [5]. In addition, some engineering properties of garlic as a function of moisture content were determined [6].

MATERIALS AND METHODS

Fresh, well matured and cured garlic bulbs of cultivar *Yamuna Safed-3* (G-282) bulbs were used in the present studies. The moisture content of garlic was determined using convection oven method [7]. Garlic plant samples were weighed and placed in an oven. The samples were heated at 100±0.5°C until constant weight was obtained. The samples were subsequently taken out and cooled in desiccators before weighed in electronic balance. All biometric and engineering properties of garlic plant were determined at three different levels of plant moisture content.

Number of leaves per plant and Length of garlic plant

Number of leaves per plant and length of plants were measured at different levels of plant moisture content. The observations were taken by counting the number of mature and green leaves per plant at the crop harvesting stage. Length of garlic plants was measured with the help of a linear scale.

Weight of garlic bulb with leaves

Weight of garlic plant with leaves was measured with the help of an electronic weighing balance having least count of 0.01 g.

Polar diameter, equatorial diameter and shape factor

These parameters were measured with the help of a digital vernier calliper having least count of 0.01 mm. Shape factor decides whether garlic bulb is oblate or prolate. It is the ratio between equatorial diameter and polar diameter.

Angle of rolling resistance

Angle of rolling resistance of garlic plant was measured on mild steel surface by inclined plane method [8]. The garlic plant was kept horizontal on the plate of the instrument and the slope was gradually increased. The angle at which impending slip occurred was measured.

Crushing and cutting resistance

Crushing and cutting resistance of garlic bulb were measured with the help of texture analyser. Texture analyser consists of a crushing probe fixed at the lower end of load cell. A base plate fixed at the lower end of texture analyser hold a garlic bulb in such a way that the centre of bulb faced the crushing probe. After adjustment of settings of texture analyser, garlic bulb was kept on the base plate and the crushing probe was moved in downward direction crushing the bulb at the centre. Vertical loading of 500 N was applied at a test speed of 0.2 m s^{-1}. The peak force of crushing and cutting was recorded.

RESULTS AND DISCUSSION

The results of experiments for biometric and engineering properties of garlic plant are presented below.

Number of leaves and plant length

The number of leaves per plant at its harvesting stage ranged between 5 to 7, with modal value of 5 at all three levels of plant moisture content. Though the number of leaves per plant remained same at different moisture levels of garlic plant, the length of garlic plant decreased from 696 to 684 mm as plant moisture content decreased from 42.38 to 36.21 % (db) as shown in Fig. 1. The relationship between length of garlic plant and moisture content can be represented by the following equation:

$$L_P = 162.25 + 25.058\ M - 0.2941\ M^2 \quad [1]$$

Where L_P is length of plant, M is moisture content (%, d.b) with the value for the

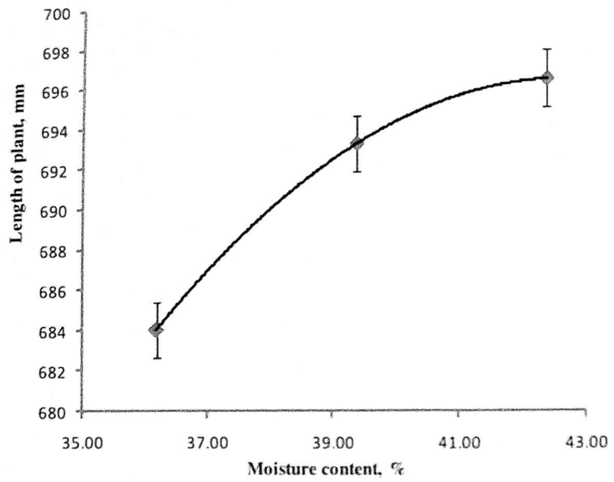

Fig. 1. Effect of garlic plant moisture content on its length

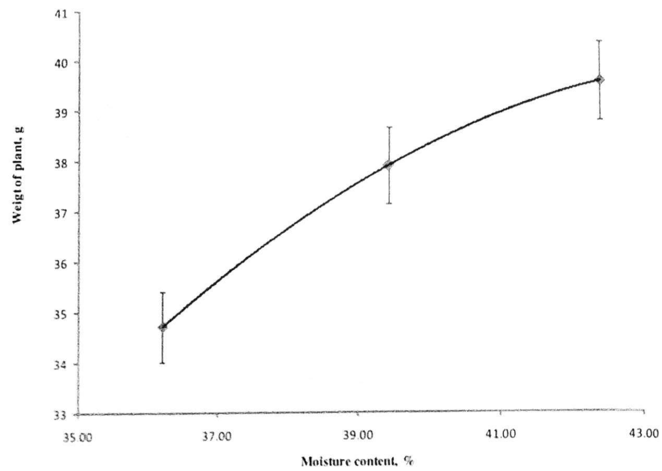

Fig. 2. Effect of garlic plant moisture content on weight of plant

coefficient of determination, R^2, being 0.99.

Weight of garlic bulb with leaves

The weight of garlic was found to decrease from 39.57 to 34.71 g, as moisture content decreased from 42.38 to 36.21 % (d.b) as shown (Fig. 2). The relationship between weight of garlic plant and moisture content can be represented by following equation:

$$W_P = -96.69 + 6.056\ M - 0.067\ M^2 \quad (2)$$

Where W_P is weight of plant, M is moisture content (%, d.b) with the value for the coefficient of determination, R^2, being 0.972.

The negative linear relationship was also observed for soya bean [9], white lupin [10] and okra seed [8].

Polar diameter and equatorial diameter

The polar diameter of garlic bulb increased significantly with decrease in garlic plant moisture content. It increased from 36.72 to 40.49 mm as plant moisture content decreased from 42.38 to 36.21 % (db). Similar trend was found for equatorial diameter as it increased from 34.07 to 37.95 mm (Fig. 3).

The relationship of polar diameter and equatorial diameter of garlic bulb with

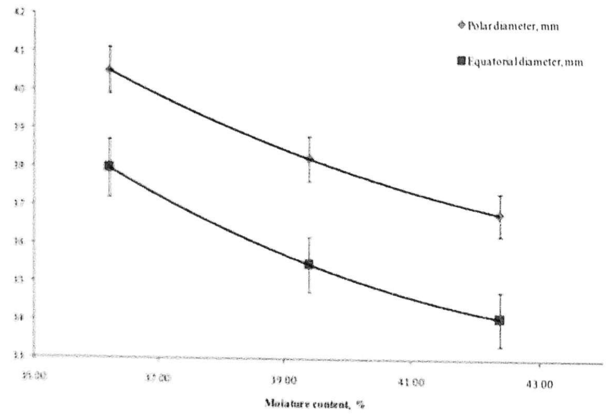

Fig. 3. Effect of garlic plant moisture content on polar diameter and equatorial diameter of bulb

moisture content can be represented by following equations:

$$D_P = 124.09 - 3.759\ M + 0.0401\ M^2 \quad (3)$$

$$D_E = 142.08 - 4.795\ M - 0.053\ M^2 \quad (4)$$

Where D_P is polar diameter of garlic bulb, D_E is equatorial diameter of garlic bulb, M is moisture content (%, d.b) with the value for the coefficient of determination, R^2, for both relationships being 0.974.

Shape factor

The shape factor of garlic bulb was found to increase from 0.91 to 0.94 with decrease in plant moisture content from 42.38 to 36.21 % (d.b). The relationship between shape factor and moisture content is shown by following equation:

$$S_f = 0.948 - 0.011\ M \qquad (5)$$

Where S_f is shape factor of garlic bulb, M is moisture content (%, d.b) with the value for the coefficient of determination, R^2, being 0.98.

Angle of rolling resistance

Results showed that angle of rolling resistance increased significantly with decrease in the moisture content of garlic plant. Angle of rolling resistance ranged from 22.64° to 35.64° with change of moisture content 42.38 to 36.21 % (d.b). The relationship between angle of rolling resistance and moisture content is shown by the following regression equation:

$$A_R = 248.95 - 9.123\ M + 0.0893\ M^2 \qquad (6)$$

Where A_R is angle of rolling resistance, M is moisture content (%, d.b) with the value for the coefficient of determination, R^2, is 1.0 (Fig. 4).

Similar trends were observed by Singh & Goswami [11] and Sahoo & Shrivastava [8] for cumin seeds and okra seeds, respectively, in terms of coefficient of static friction.

Crushing and cutting resistance

Crushing resistance of garlic bulb was found to increase with decrease in moisture content. Similarly, cutting resistance of garlic plant was also found to increase with decrease in moisture content (Fig. 5). Following equations show the relationship of crushing resistance (R_{Cr}) and cutting resistance (R_{Cu}) with the moisture content of plant:

$$R_{Cr} = 87.35 + 34.50\ M - 0.6043\ M^2 \qquad (7)$$

$$R_{Cu} = 727.17 - 16.53\ M + 0.1068\ M^2 \qquad (8)$$

The value of coefficient of determination R^2 for both of relationship was 0.958.

The increase in crushing and cutting resistance with decrease of moisture content was also reported earlier [6]. Hence, the information generated on the above biometric and engineering properties of garlic can be used for design of mechanical harvester for garlic.

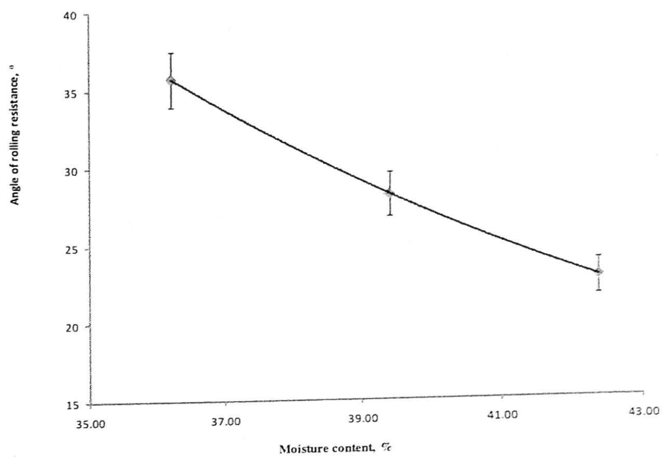

Fig. 4. Effect of garlic plant moisture content on angle of rolling resistance

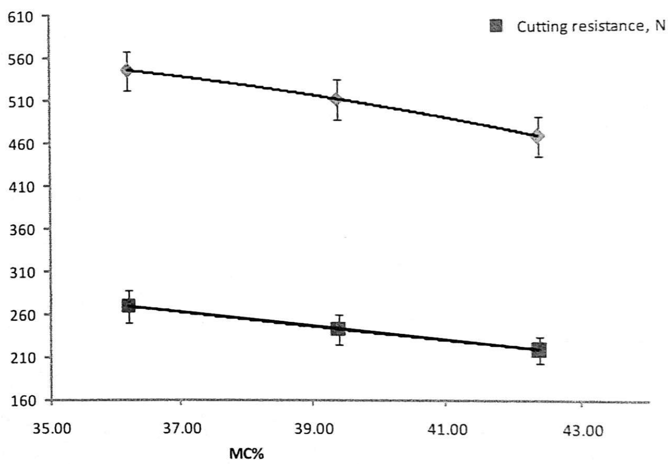

Fig. 5. Effect of garlic plant moisture content on crushing and cutting resistance

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