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Physical Properties of Cabbage for Mechanical Harvesting

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Abstract: India is the second largest producer of cabbage (*Brassica oleracea)* in the world. Cabbage is a kind of common-planted vegetable which is originated in Cyprus and around the Mediterranean coast. The cultivated area is about 400138 ha with a production of 9039219 MT per year i.e. about 12.80 % of total world production and has rank 6th among all the vegetables in India (NHB, 2015). But all of these cabbages are now harvested by hand, and it is becoming increasingly difficult for growers to employ enough skilled workers for this laborious task because of the urbanization. Because of this, agriculture's economic contribution to India's GDP is steadily declining with wide-based economic growth in the nation. Therefore, this situation demands industries to promote the project of developing a cabbage harvester in place of manual work. In the 20th century, several researchers had examined the physical properties of cabbage and had applied their findings to design the components of cabbage harvester. But most of the machines, thus produced, had a limited use for either industrial use or fresh market. Some designers had constructed harvester for industrial use without knowing its physical properties. Thus, leaded to failure.

Keywords: Cabbage, Coefficient of variance, Head shapes, Pusa drumhead, Pusa Mukta, September Early, Pulling force.

I. INTRODUCTION

Agriculture plays an important role in economic development in India. The efficient utilization of the resources and India is the second largest in farm output, seventh largest in its export worldwide. Due to its Climate and variety of soil, it is possible to grow large variety of crops such as cereal crops, vegetables and commercial crops etc. Agriculture and its associated industry add to the Gross Domestic Product (GDP) by a large amount. About 50% of people are associated with it directly. Major cabbage producing states in India are Uttar Pradesh, Orissa, Bihar, Assam, West Bengal, Maharashtra and Karnataka in which West Bengal topped in production and encountered about 24 % total production of India followed by Orissa and Bihar. In India every state grow cabbage except Jammu & Kashmir, Goa and Kerala. The production trend of cabbage shows an increment of about 6268 '000 MT in last 14 years counted from 1991 to 2014 [7]. But productivity trend is remained constant and even less than the average of other countries i.e. 22.6 MT/ha. Productivity wise South Korea is in top having 71.2 MT/ha productivity.

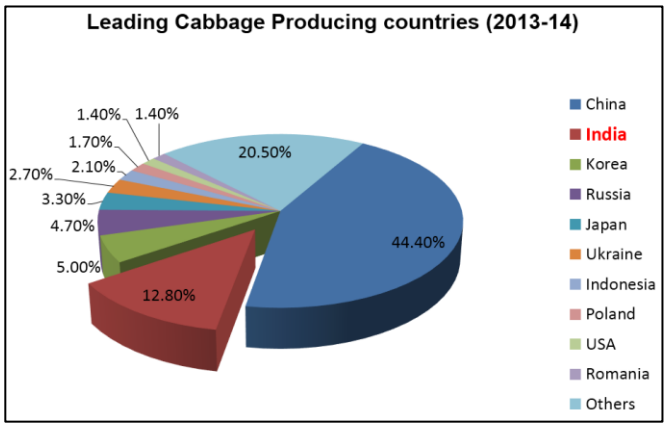

Fig. 1 Proportion of production costs for cabbage production (2013-14) [7]

The main reason behind the low productivity in India is they still follow traditional methods of transplanting and harvesting which requires lots of skilled labor and capital. Alone harvesting requires more than 50% of processing cost. Thus, there is a need of mechanization in the harvesting process of cabbages. For harvesting machine design, the first and vital step is to determine the physical properties of cabbage relevant to mechanical harvesting.

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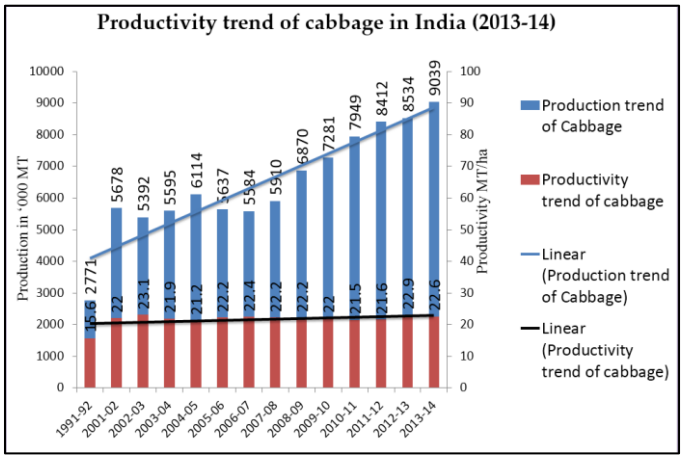

Fig. 2 Productivity trend of cabbage in India (2013-14) [7]

A. *Climate Requirement*

Cabbage has the adaptability to the wide range of climatic conditions but the most favorable condition for growing cabbage is mentioned below.

1. It grows well in moist and cool climate. Dry and low humidity is not good for cabbage.
2. The brassica family is quite cold resistant. Young, hardened cabbage plants can withstand temperatures of 0 °C for less than 36 hours.
3. The optimum growing temperature for this crop is between 15 and 22 °C.
4. The minimum, optimum and maximum germination temperatures for cabbage are 7, 27 and 29 °C respectively. 5. High temperatures gives poor quality of curds. Cool temperatures delay maturity and undersized curd.
6. Water requirements vary from 380 to 500 mm per crop, depending on climate and length of growing season.

B. *Soil Requirement*

Cabbage requires good drainage condition. Sandy loam soil is a best suited for early crops, but clay loam and loam soil is preferred for late crop. The favorable pH for the growth of cabbage is about 6.2 to 6.8.

C. *Harvesting season of cabbage*

The cabbage is generally comprising of early season type crop that grown in June and July has a harvesting season in October to November and late season type crop grown in November and December has February to march as a harvesting season.

II. MATERIALS AND METHODS

The experiment was conducted in a village near Kurukshetra, Haryana, India from 3 November 2018 to 20 November. The soil was a sandy loam having pH 6.8, containing total N (2.9%), total C (1.1%), thus C/N ratio of 2.64. The land was prepared through plowing and disking and then formed into beds prior to transplanting of the experimental plants. Transplanting took place at 45X45 cm distance between plants and within plant rows respectively. Irrigation was applied 5 times in an interval of about 7 to10 days.

For Physical properties estimation, the cabbage plant was divided into four basic segments; the head, the leaves, and the stump. In this study, three basic head shapes are postulated to exist for the varieties of cabbage (Gilbert 1969). These four shapes are Sphere, Elliptical, Teardrop, and Inverted teardrop. The stump consisted of the leaf stem, the stump length, and the attached roots. The spacing of the leaves on the leaf stem is assumed to be constant along the leaf stem, and the measurement of this quantity is at a point midway between lowest between the lowest feeder leaf and he base of the head. The leaf stem was assumed to be a right circular cylinder and the leaf weight was assumed to be linearly distributed along the leaf stem (Gilbert, 1969). This assumption is reasonable since the leaf size decreases as the spacing of the leaves decreases near the head.

A statistical analysis was performed to determine the maximum, minimum, mean, standard deviation, variance, and coefficient of variability of each physical quantity for three varieties of cabbages including Pusa Mukta, Pusa Drumhead and September early. Ten samples of each variety were taken for study.

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III. EQUATIONS

The following limits for knowing the shape of cabbage were applied for each variety (Gilbert, 1969).

Spherical:
HD= HH + ½ (Inches)
Elliptical:
HD> HH + 1 (Inches)
Teardrop:
HD> HH + 1 and HTMD< ½ HH – ½ (Inches)
Inverted teardrop:
HD>HH + 1 and HTMD < ½ HH + ½ (Inches)

Where,
HTMD- Height to maximum head diameter
FLD- Feeder leaf diameter
LSL- Leaf stem length
SD- Stump diameter
HD- Head diameter
SL- Stump length
HH- Head height
SOL- Spacing of leaves
Q- Feeder leaf angle

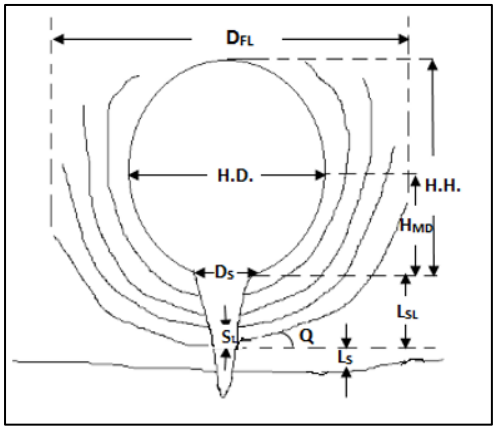

Fig. 3 Dimension of Cabbage

Assuming the correlation between plant parts, t- values were calculated. Horizontal pulling force and vertical pulling force were also measured using mechanical force gauge.

IV. OBSERVATIONS

A statistical analysis was performed to determine the maximum, minimum, mean, standard deviation, variance, and coefficient of variability of each physical quantity for three varieties of cabbages including Pusa Mukta, Pusa Drumhead and September early. Below, all the units are in MKS system i.e. all the weights are in kilograms and all the heights, length and diameters are in meters. The vertical and horizontal pulling force are in newton and feeder leaf angle is in degrees S.D. =Standard variation and C.O.V. =Coefficient 0f Variance.

TABLE 1
VARIETY: PUSA MUKTA
HEAD SHAPE: ELLIPTICAL
NO. OF SAMPLES: 10

Physical properties	Maximum	Minimum	Mean	Variance	S.D.	C.O.V.
Head weight	1.873	0.860	1.388	0.09590	0.3096	22.305
Leaf weight	1.191	0.516	0.892	0.03750	0.1938	21.733
Stump weight	0.397	0.175	0.259	0.00598	0.0767	29.624
Head height	0.162	0.114	0.138	0.00031	0.0176	12.772
Head diameter	0.184	0.152	0.163	0.00009	0.0092	05.627
Height to maximum diameter	0.092	0.066	0.078	0.00010	0.0101	13.032
Stump diameter	0.044	0.035	0.040	0.00001	0.0034	08.437
Leaf stem length	0.095	0.057	0.074	0.00013	0.0114	15.343
Stump length	0.083	0.044	0.063	0.00013	0.0116	18.442
Max. feeder leaf diameter	0.610	0.381	0.528	0.00528	0.0726	13.750
Spacing of leaves	0.013	0.006	0.010	0.00001	0.0028	28.571
Vertical pulling force	200.00	125.00	155.85	462.110	21.50	13.793
Feeder leaf angle	60	0	10.173	81.065	9.0036	88.505

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TABLE 2
VARIETY: PUSA DRUMHEAD
HEAD SHAPE: SPHERICAL
NO. OF SAMPLES: 10

Physical properties	Maximum	Minimum	Mean	Variance	S.D.	C.O.V.
Head weight	4.989	0.517	2.829	0.77900	0.8820	31.199
Leaf weight	1.708	0.397	0.915	0.09800	0.3130	34.208
Stump weight	3.998	0.650	1.376	0.06700	0.2590	18.823
Head height	0.254	0.140	0.196	0.00046	0.0215	10.969
Head diameter	0.247	0.130	0.205	0.00076	0.0276	13.463
Height to maximum diameter	0.140	0.064	0.101	0.00020	0.0140	13.916
Stump diameter	0.048	0.025	0.039	0.00002	0.0039	10.000
Leaf stem length	0.089	0.032	0.060	0.00011	0.0104	17.450
Stump length	0.089	0.013	0.029	0.00011	0.0103	35.640
Max. feeder leaf diameter	0.965	0.483	0.697	0.00082	0.0906	12.999
Spacing of leaves	0.016	0.006	0.010	0.00001	0.0020	19.417
Vertical pulling force	190.00	40.00	87.00	725.960	26.944	30.970
Horizontal pulling force	178.00	40.000	86.551	725.660	26.938	31.124
Feeder leaf angle	20.00	0.00	5.328	26.2700	5.125	96.198

TABLE 3
VARIETY: SEPTEMBER EARLY
HEAD SHAPE: ELLIPTICAL
NO. OF SAMPLES: 10

Physical properties	Maximum	Minimum	Mean	Variance	S.D.	C.O.V.
Head weight	5.902	0.794	2.686	0.81230	0.9012	33.551
Leaf weight	1.532	0.227	0.584	0.04950	0.2225	38.092
Stump weight	1.476	0.170	0.602	0.05130	0.2265	37.624
Head height	0.232	0.124	0.175	0.00047	0.0220	12.571
Head diameter	10.75	0.130	0.192	0.00078	0.0279	14.531
Height to maximum diameter	0.273	0.057	0.092	0.00018	0.0135	14.610
Stump diameter	0.051	0.025	0.037	0.00002	0.0044	11.957
Leaf stem length	0.102	0.025	0.048	0.00016	0.0125	25.880
Stump length	0.108	0.013	0.051	0.00023	0.0151	29.550
Max. feeder leaf diameter	0.889	0.356	0.615	0.01041	0.1020	16.585
Spacing of leaves	0.016	0.006	0.011	0.00001	0.0023	20.354
Vertical pulling force	220.00	45.000	115.00	1097.50	33.128	28.807
Horizontal pulling force	140.00	45.000	90.00	580.850	24.101	26.779
Feeder leaf angle	30.00	0.000	6.731	39.400	6.277	93.254

V. RESULTS AND DISCUSSION

A statistical analysis was performed to determine the maximum, minimum, mean, standard deviation, variance, and coefficient of variability of each physical quantity for three varieties of cabbages including Pusa Mukta, Pusa Drumhead and September early. Assuming the correlation between plant parts, t- values were calculated. Horizontal pulling force and vertical pulling force were also measured using mechanical force gauge. For all three varieties, 10 no. of samples were taken, and their shapes were studied.

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From this statistical analysis, the following extreme values for the limiting parameters have been determined for different techniques (Table 1 to 3). The maximum feeder leaf diameter which must be accommodated by a mechanical harvester was 0.9652 m. for the stump diameter, a parameter which must be accommodated by all the techniques of harvesting, maximum value observed was 0.0510 m. The force to remove the plant from soil varied with varieties, soil type and soil conditions. The maximum and minimum value for horizontal pulling force was measured as 178 N and 40 N respectively. Whereas, the vertical pulling force varied between 200 N to 45 N. On the other hand, stump length varied from 0.1080 to 0.0127 m having a mean of 0.0511m and feeder leaf angle ranges from 0 to 60 degrees. Weight of cabbage has a variation between 10.695 kg to 3.461 kg including head weight, outer leaf weight and stump weight. The height of head that a conveyor should accommodate must be between 0.2320 m to 0.1143 m. The correlations between the different plant parts were evaluated (Table 4 and 5).

TABLE 4 CORRELATIONS BETWEEN PLANT PARTS

Variety		**H_{MD}**	**H.D. and L_S**	**H.D. and D_{FL}**	**H_{MD} and L_S**	**H_{MD} and D_{FL}**	**L_S and D_{FL}**	**H.H. plus L_{SL} and H.H.**	**H.H. plus L_{SL} and L_{SL}**
Pusa Mukta	R	-0.332	-0.257	0.250	0.064	-0.621	0.522	0.412	0.924
	t	-0.986	-0.785	0.729	0.181	-2.241	1.732	1.280	6.842
Pusa Drumhead	R	0.676	0.007	0.579	-0.000	0.449	-0.032	0.903	0.469
	t	9.928	0.074	7.713	-0.763	5.462	-0.763	22.835	5.762
September Early	R	0.614	0.037	0.463	-0.076	0.380	-0.093	0.918	0.725
	t	8.231	0.433	5.497	-0.811	4.479	-0.997	25.231	11.653

H_{MD} = Head height above major diameter, H.D. = Head Diameter, L_S = Stump Length, D_{FL} = Feeder Leaf Diameter, L_{SL} = Leaf Stem Length and H.H. = Head Height.

TABLE 5 CORRELATIONS BETWEEN PLANT PARTS CONTINUED

Variety		**H_T**	**L_{SL} and H.D.**	**L_{SL} and H_{MD}**	**L_{SL} and L_S**	**L_{SL} and D_{FL}**	**H_T and H.D.**	**H_T and H_{MD}**	**H_T and L_S**	**H_T and D_{FL}**
Pusa Mukta	R	0.797	0.431	-0.434	-0.589	0.018	0.187	-0.156	-0.156	0.198
	t	3.739	1.355	-1.363	-2.067	0.051	0.538	-0.451	-0.446	0.571
Pusa Drumhead	R	0.377	0.116	0.036	-0.150	0.197	0.734	0.616	0.372	0.523
	t	4.435	1.265	0.395	-1.654	2.204	11.476	8.506	4.188	6.671
September Early	R	0.517	0.192	0.315	-0.412	0.377	0.616	0.690	0.245	0.495
	t	6.506	2.099	3.610	-4.912	4.332	8.499	10.377	2.740	6.132

H_T = Total Plant Height, H_{MD} = Head height above major diameter, H.D. = Head Diameter, L_S = Stump Length, D_{FL} = Feeder Leaf Diameter, L_{SL} = Leaf Stem Length and H.H. = Head Height.

V. CONCLUSIONS

In this study, the cabbage plant shape is categorized into 4 types i.e. Spherical, Elliptical, Teardrop and Inverted Teardrop. For experiment, 3 famous varieties of India were selected namely Pusa Mukta, Pusa Drumhead and September Early. The characteristic geometric dimension of each varieties was evaluated along with the force required for pulling out of cabbages from the soil. On the basis of these dimensions, some limited values for designing were set. According to the results, the harvester should have the strength to resists a horizontal pulling force of 178 N and vertical pulling force of 200 N. The passage of opening of harvester should be in such a way that it could accommodate the head height of 0.2320 m (minimum) to 0.1143 m (maximum) of cabbage.

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