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Investigation of Engineering Properties of Vegetable Seeds Required for the Design of Pneumatic Seeder

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A B S T R A C T

The intervention of engineering properties of the seeds has an important role in design of pneumatic seeder for seeding in plug trays. The present study was carried out to find different physical properties like seed size (length and width), shape, thousand seed weight, bulk density and terminal velocity (aerodynamic property) of cabbage (*Brassica oleracea*) and tomato (*Lycopersicon esculentum*) seeds at moisture content of $8.24\%_{(wb)}$ and $9.71\%_{(wb)}$, respectively. The size of the seeds was measured by analysing with 'Adobe Photoshop CS4' package by acquiring the digital images with a flatbed scanner. The shape of seeds was expressed in terms of roundness by calculating number of pixels covered by digital image of seed area having 300 dpi. The terminal velocity of five randomly selected samples were studied in terminal velocity apparatus (attached with vane probe anemometer) to find the minimum-negative pressure to identify vacuum requirement in seed suction tube. The average length and width of cabbage was found to be 2.03 ± 0.06 and 1.78 ± 0.05 mm whereas, the tomato seeds of 3.97 ± 0.10 mm length and 2.96 ± 0.07 mm of width were noticed in the study for deciding needle diameter of suction tube. The roundness factor was found to be 0.85 ± 0.03 and 0.64 ± 0.02 for cabbage and tomato seeds, respectively. The thousand seed weights of cabbage and tomato seeds were 3.40 ± 0.05 g and 2.63 ± 0.04 g, respectively. The bulk density of 0.73 g/cc and terminal velocity of 7.28 ± 0.04 m/s were observed for cabbage seeds, similarly they were 0.30 g/cc and 2.67 ± 0.06 m/s for tomato seeds, respectively. All engineering properties of both type of seeds found significantly different, when compared with each other. The length of both type of seeds have positive correlation with width and negative correlation with height. There was no correlation among the other properties. The significant difference was obtained among the properties, while correlation of length of seeds was found with their width and roundness only.

Introduction

Engineering properties of the seeds influence the performance of seed singulation mechanism in terms of pickup, singulation and drop of seeds (Tang *et al.*, 2015). In the proposed study, the engineering properties of two different vegetable seeds having good production share were studied *viz*. cabbage (*Brassica oleracea*) and tomato (*Lycopersicon esculentum*) (NHB, 2015). The physical properties *viz.* seed size (length and width), shape, thousand seed weight, bulk density and terminal velocity (aerodynamic property) were important design related properties of seeds (Salawu *et al.*, 2014), were measured. The physical properties of the seed like length, width were assisted in determining the selection of the diameters of the picking needles whereas the seed properties like mass of the seeds and terminal velocity was assisted in establishing the minimum suction pressure required for picking the seeds.

Several methods had been advised by the researchers to determine the engineering properties of different seeds. Waziri and Mittal (1983) used an overhead projector to trace the outline of the projected boundary to determine the axial measurements using the magnification factor of projection. The seed was placed in natural rest position and vertical position to obtain major, minor and intermediate diameters. It was reported that sorghum and pearl millet kernel were spherical with the average diameter of 2.72 ± 0.14 mm and 2.21 ± 0.19 mm, respectively. Churchill *et al.*, (1992) reported machine vision to be more accurate and efficient in measuring dimensions of seeds than trained inspectors working with microscopes. Churchil and Bilsland (2001) measured seed dimensions of tall fescue, orchard grass, and perennial ryegrass using digital imaging (Machine Vision System, MVS), and compared with the measurements taken using stereomicroscope. An average difference of 2.2 per cent was reported in the mean widths measured by MVS and human operators. The degree of accuracy was found to be acceptable. It was also reported that for this research, human measurers complained of eye fatigue. The human measurement was equivalent to 1 minute 27 seconds per seed compared with 31 seconds per seed with MVS. Cheng and YiBin (2004), Shahin and Symons (2005) as well as Mandal *et al.*, (2012), also used Image analysis with MATLAB software for seed sizing of different seeds of spherical as well as non-spherical shape.

Materials and Methods

The cabbage variety GOLDEN SELECTION (IMP.) and tomato variety DS-21 was used for the conduction of the experiments. Before determining the engineering properties of seeds the moisture content of seeds were checked using hot air oven method (make Contemp, model CEI-248). The moisture content found was 8.24% and 9.71% for cabbage and tomato respectively on wet basis.

Physical properties of seeds

Physical properties of seeds as relevant to the design of the nursery tray seeder were determined as follows

Size

Seed size is characterised as seed length and seed width. These factors were considered as important for determining the inner diameter of the suction needles. The measurements of 25 random samples of each type of seed were taken by sticking seeds on different colour paper sheet for easy detection of the boundaries of seeds *i.e.* tomato on black sheet and cabbage on white sheet.

These characters were obtained from digital images acquired with a flatbed scanner (make Hewlett-Packard, Model Precision Scan Pro 3.02), with a resolution of 300 dpi; the images were stored in.jpeg format. The dimensions of the seeds were measured by analysing these images using the image analysis software 'Adobe Photoshop CS4'. The width determination of single cabbage seed is shown in figure 1.

Shape

The shape of a seed is expressed in terms of roundness. The per cent roundness was calculated by taking ratio of projected area to the area of smallest circumscribing circle (Mohsenin, 1965).

The projected area of the seeds was measured by image analysis method using 'Adobe Photoshop CS4' software by calculating number of pixels covered by seed area (Fig. 2). One centimetre square area was scanned with same procedure and conditions which were used for calibrating pixel area.

The number of pixels covered by square area was calculated by software and with relating number of pixels the seed area were determined. The area of the smallest circumscribing circle was calculated by taking the largest axial dimension of the seed at natural rest position as the diameter of the circle. This procedure was repeated for 25 randomly selected samples for both types of seed. The mean value was taken as the characteristic value of roundness.

Thousand seed weight

The weight of the seed directly influences the suction pressure needed to pick up the seed is directly proportional to its weight. 25 random samples of one thousand seeds of each type was selected and weighed on a precision weighing balance (make Wensar, Model PGB200). Figure 3 shows the setup used for measuring the 1000 seed weight of the cabbage as well as tomato seeds.

Seed bulk density

The volume of seed holder depends upon the bulk density of seeds. 25 random samples of each seed type were used to determine seed bulk density. The samples were filled in container and weighed on weighing balance (make Wensar, Model PGB200). Distilled water (sp. gra. = 1) was used to determine the exact volume of container used. Bulk density of seeds was calculated by taking ratio of weight of seeds in container (g) and volume of container (cc).

Aerodynamic properties of seeds (Terminal velocity)

Aerodynamic properties (terminal velocity) of seeds were required for establishing the minimum negative pressure level for design of the pneumatic seeder. Terminal velocity is the air velocity at which a particle remains in suspended state in a vertical pipe. 25 random samples of each type of seed were selected and their terminal velocity was measured using a terminal velocity measurement apparatus (Fig. 4). Anemometer vane probe (make Lutron, Model AM-4201) was used to measure the terminal velocity. The terminal velocity obtained was used to determine the minimum air flow rate required to be maintained in the seeder pipe and consequently used to determine the inner diameter of the seeder pipe.

Statistical analysis

The properties were analysed using SAS 9.3 software. The mean and standard deviation (S.D.) was calculated for each property of cabbage and tomato seeds. The completely randomized design was used to investigate the significance of data and correlation between properties was also found.

Results and Discussion

The mean and standard deviation of engineering properties of cabbage and tomato seeds are given in table 1 and properties are discussed as follows

Physical properties

The size, shape, thousand seed weight and bulk density of both types of seeds were calculated and tested for their significance.

The details of results are discussed separately as below

Size

The length of cabbage seeds was ranged between 1.71-2.34 mm and the range was 3.49-4.54 mm for tomato seeds. The average width of cabbage and tomato seeds lied within 1.51-2.14 mm and 2.62-3.32 mm, respectively.

According to ANOVA (Table 2) the length of cabbage and tomato seeds was different at 1 per cent level of significance. The coefficient of determination (R^2) for the length was 0.94, while the coefficient of variance (C.V.) was 8.07 per cent for the length.

Table 3 shows the ANOVA for width of both types of seeds. The difference between width of both types of seeds was found to be highly significant with R^2 0.92 and C.V. 7.33 per cent.

Shape

The shape of the seed was expressed in terms of roundness which was found to be 0.70-0.99 for cabbage while for tomato seeds it was ranged between 0.55-0.71. The projected area influences the drag coefficient of a seed in airflow and thus it influences the ability of the seed to be picked up by the needle.

The ANOVA for the roundness is given in Table 4. From the ANOVA it was found that the roundness of cabbage and tomato seeds was significantly different at 1 per cent level of significance. The R^2 observed was 0.72 and coefficient of variance 8.79 per cent for the roundness of seeds.

Fig.1 Width determination using 'Adobe Photoshop CS4'

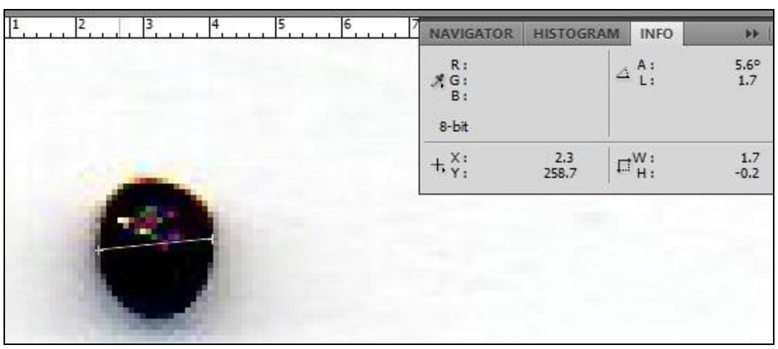

Fig.2 Projected area calculation using 'Adobe Photoshop CS4'

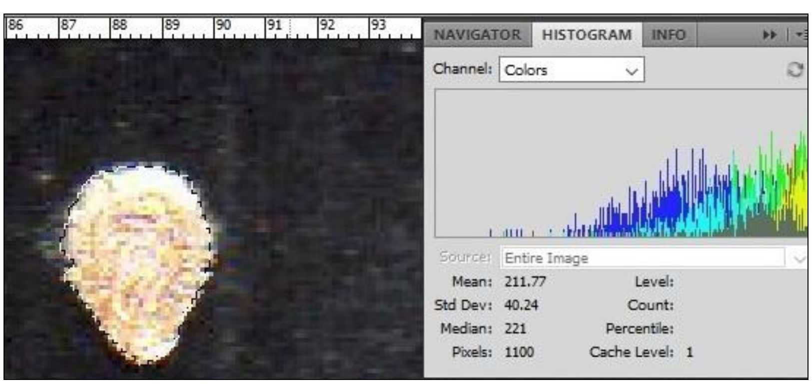

Fig.3 Measurement of 1000 seed weight

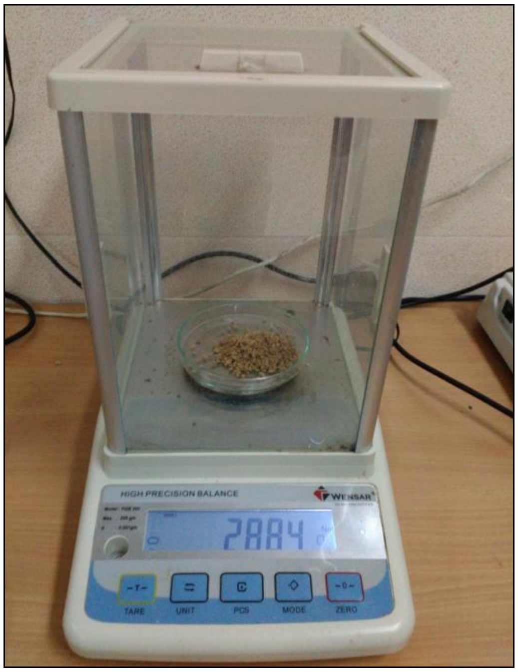

Fig.4 Setup for measurement of terminal velocity

Table.1 Sample statistics of the data for cabbage and tomato seeds

Variable	N	Cabbage		Tomato	
		Mean	Std Dev	Mean	Std Dev
Length	25	2.03	0.20	3.94	0.28
Width	25	1.79	0.15	2.92	0.19
Roundness	25	0.85	0.08	0.64	0.05
Thousand seed weight	25	3.41	0.08	2.62	0.05
Bulk density	25	0.73	0.002	0.30	0.01
Terminal velocity	25	7.29	0.031	2.35	0.05

Table.2 ANOVA for lengths of cabbage and tomato seeds

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	45.48672200	45.48672200	782.96	<.0001
Error	48	2.78861600	0.05809617		
Corrected Total	49	48.27533800			

$CD_{0.05} = 0.14$

Table.3 ANOVA for width of cabbage and tomato seeds

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	16.09713800	16.09713800	540.66	<.0001
Error	48	1.42911200	0.02977317		
Corrected Total	49	17.52625000			

$CD_{0.05} = 0.10$

Table.4 ANOVA for roundness of cabbage and tomato seeds

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.53251200	0.53251200	124.70	<.0001
Error	48	0.20497600	0.00427033		
Corrected Total	49	0.73748800			

$CD_{0.05} = 0.04$

Table.5 ANOVA for thousand seed weight of cabbage and tomato seeds

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	7.83604872	7.83604872	1745.90	<.0001
Error	48	0.21543600	0.00448825		
Corrected Total	49	8.05148472			

$CD_{0.05}$ = 0.04

Table.6 ANOVA for bulk density of cabbage and tomato seeds

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	2.27868552	2.27868552	142834	<.0001
Error	48	0.00076576	0.00001595		
Corrected Total	49	2.27945128			

$CD_{0.05}$ = 0.002

Table.7 ANOVA for terminal velocity of cabbage and tomato seeds

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	305.5392000	305.5392000	195254	<.0001
Error	48	0.0751120	0.0015648		
Corrected Total	49	305.6143120			

$CD_{0.05}$ = 0.02

Thousand seed weight

The thousand seed weights of cabbage and tomato seeds were found to lie between 3.278-3.522 g and 2.539-2.723 g, respectively. According to ANOVA (Table 5) the thousand seed weight of cabbage and tomato seeds was different at 1 per cent level of significance. The coefficient of determination for this property was 0.97, while the coefficient of variance (C.V.) was 2.22 per cent for the thousand seed weight.

Bulk density

The bulk densities of cabbage and tomato seeds were found to be 0.725-0.732 g/cc and 0.293-0.311 g/cc, respectively. Table 6 shows the ANOVA for bulk density of both types of seeds. The difference between bulk density of both types of seeds was found to be highly significant with R^2 0.99 and C.V. 0.77 per cent.

Aerodynamic properties

The selection of seeder pipe diameter was based on minimum terminal velocity observed amongst the two types of seeds. The mean terminal velocities of cabbage and tomato seeds were found to be 7.23-7.33 m/s and 2.27-2.43 m/s respectively. The ANOVA for the terminal velocity is given in Table 7. From the ANOVA it was found that the terminal velocity of cabbage and tomato seeds was significantly different at 1 per cent level of significance. The R^2 observed was 0.99 and coefficient of variance 0.82 per cent for the terminal velocity of seeds.

Correlation coefficient

The Pearson correlation coefficients were calculated to find the correlation between engineering properties of both types of seeds separately. The length of cabbage seeds had a positive correlation with its width with Pearson correlation coefficient 0.59. In addition to that also a negative correlation was found between length and roundness of cabbage seeds with Pearson correlation coefficient -0.69. There was no other pair of engineering properties of cabbage seeds was found to be correlated with each other.

In case of tomato seeds, the length had a positive correlation with its width with Pearson correlation coefficient 0.59, whereas Pearson correlation coefficient -0.64 was found between length and roundness of tomato seeds which was a negative correlation. The other properties of tomato seeds had not showed any correlation between them.

The average length of cabbage and tomato seeds was found to be 2.03 ± 0.06 mm and 3.97 ± 0.10 mm, respectively. The average width of cabbage and tomato seeds was found to be 1.78 ± 0.05 mm and 2.96 ± 0.07 mm, respectively. As the size of cabbage seeds found less it would require smaller diameter pickup device. The shape of the seed was expressed in terms of roundness which was found to be 0.85 ± 0.03 and 0.64 ± 0.02 for cabbage and tomato seeds, respectively. As the roundness found more for cabbage seeds, it was more round than tomato seeds. The thousand seed weight of cabbage and tomato seeds was found to be 3.40 ± 0.05 g and 2.63 ± 0.04 g, respectively. Hence cabbage seeds had needed more suction pressure than tomato seeds. The bulk densities of cabbage and tomato seeds were found to be 0.73 ± 0.00 g/cc and 0.30 ± 0.00 g/cc, respectively, as a result of it the cabbage seeds supposed to require larger volume of seed holder. The mean terminal velocities of cabbage and tomato seeds were found to be 7.28 ± 0.04 m/s and 2.67 ± 0.06 m/s respectively.

All engineering properties of both type of seeds found significantly different, when compared with each other. The length of both type of seeds have positive correlation with width and negative correlation with height. There was no correlation among the other properties.

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