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RESISTANCE OF BULK LATHYRUS TO AIRFLOW

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A b s t r a c t. The experiment was conducted to determine the airflow resistance of lathyrus. The raw material was brought from a university farm. Airflow resistances of three varieties of lathyrus (cv. NLK-40, Pratik and Ratan) were studied with a laboratory instrument at moisture content of 7.33 to 18.80, 6.75 to 18.30 and 7.90 to 19.40% (d.b.) for superficial air velocities ranging from 0.04 to 1.26, 0.04 to 1.40 and 0.04 to 1.48 $m^3 s^{-1} m^{-2}$ at bed depths of 0.2 to 0.6 m with bulk density ranging from 805 to 895, 795 to 875 and 770 to 850 kg m^{-3}, respectively. The airflow resistance of lathyrus increased with increase in airflow rate, bulk density, bed depth and decreased with moisture content. Modified Shedd equation, Hukill and Ives equation and modified Erguns equation were examined for pressure drop prediction. Airflow resistance was accurately described by modified Shedd equation followed by Hukill and Ives equation and modified Erguns equation. The developed statistical model, comprising airflow rate, moisture content and bulk density, could fit the pressure drop data reasonably well.

K e y w o r d s: Airflow resistance, pressure drop, lathyrus

List of symbols used

A, B – constants (–),
b_1, b_2, b_3, b_4 – regression coefficients (–),
D – depth of grain bed (m)
D_m – grain size $(LBT)^{1/3}$ where L is length, B is breadth and T is thickness (mm),
M – moisture content % (d.b.),
ΔP – pressure drop, Pa m^{-1},
R^2 – coefficient of determination (–),
Sy – standard error of estimate (–),
ε – bulk porosity (%),
ρ_t – true density (kg m^{-3}),

V – airflow rate $m^3 s^{-1} m^{-2}$,
ρ_b – bulk density kg m^{-3}.

INTRODUCTION

Lathyrus (*Lathyrus sativus* L.) is a food, feed and fodder legume (pulse) crop. It is grown on an area of about 1.5 million hectares with the annual production of 0.8 million tonnes. Nearly two-thirds of the national acreage under lathyrus is in south-eastern Madhya Pradesh, and in the *Vidarbha* region of Maharashtra. India ranks first in terms of area (1500 thousand ha), production (800 thousand tonne) and productivity (533 kg ha^{-1}) (Clayton and Campbell, 1997).

The relationship between a drop in pressure and the rate of airflow through an agricultural product is important in the design of drying or aeration systems. Resistance to airflow is a function of both product and air properties (Jayas *et al.* 1987). The study of airflow resistance through agricultural products was started by Stirniman *et al*. (1931) and continued by many others, and presented equations and curves for various grains.

The air pressure required to force air through a bed of grain is dissipated continuously due to friction and turbulence. The pressure drop for airflow through any particulate system depends on the rate and direction of airflow, surface and shape characteristics of the grain, the number, size and configuration of the voids, the particle size range, bulk density, depth of product bed, method of bin filling, fines concentration and moisture content (Brooker *et al.* 1992). The data on the airflow-static pressure relationship of a number of agricultural grains have been published in ASAE D272.3 MAR1996 (R2007), (ASABE, 2007). A number of research workers have studied pressure drop characteristics of various cereals, oilseeds, vegetable seed, root and bulb vegetables, leafy vegetables and grass seed. Forages, biomass, cotton seed and legumes were also studied, but to a very limited extent. Most of the researchers have reported airflow resistance data for agricultural grains, but for low ranges of airflow. Nimkar and Khobragade (2006) rightly pointed out that the data on airflow resistance of pulse crops are still scarce.

The phenomenon of pressure drop in airflow through agricultural products has been widely investigated for various grains (Giner and Denisienia 1996, Nimkar and Chattopadhyay 2003, Rajabipour *et al.* 2001, Sacilik 2004 and Kusinska 2008) and root vegetables (Neale and Messer 1976, Abrams and Fish 1982, Shahbazi and Rajabipour 2008 and Kasaninejad and Tabil 2009). In most cases, data were analysed by means of Shedd (1953) and Hukill and Ives (1955) equations. Both the models have been widely used because they were found to fit many experimental data sets. However, the constants in these equations have a purely empirical nature, without physical meaning. An alternative expression is the model of Ergun (1952), originally developed for packed beds of uniformly sized spheres; the equation contains a linear and a quadratic velocity term which depends on bed porosity, particle diameter and fluid properties.

Earlier reported studies on airflow resistance of different agricultural grains as affected by various operating parameters were reviewed, which showed that no design data on the resistance to airflow of lathyrus is available. Therefore, it was felt necessary to generate and provide information on airflow resistance of lathyrus to designers of drying systems for proper drying of this untapped pulse crop by forced draft. Therefore, the present investigation was planned with the following objectives:

(1) To determine pressure drop at different airflow rates through clean grain beds of lathyrus at different levels of moisture content, bulk density and bed depth.
(2) To compare suitability of mathematical relationships available for pressure drop prediction with the experimentally determined data.
(3) To develop a statistical model describing the relationship between airflow resistance and the various operating parameters for lathyrus.

MATERIALS AND METHODS

Preparation of test sample

The lathyrus samples were procured from the All India Coordinated Research Project on Lathyrus, College of Agriculture, Nagpur. The test samples of lathyrus grain varieties of NLK- 40, Pratik and Ratan, having initial moisture content of 9.47, 10.10 and 10.18% (d.b.), respectively, were sun-dried and the corresponding moisture content obtained was 7.33, 6.75 and 7.90% (d.b.), respectively.

Sun-dried sample was moistened with a calculated quantity of water and conditioned to raise its moisture content to the desired level by using the method suggested by Nimkar and Chattopadhyay (2003) and Jekayinfa (2006).

Determination of physical properties

The relevant physical properties, viz., grain size (D_m), *in-situ* bulk density (ρ_b), true density (ρ_t), and bulk porosity (ε) were measured for five representative samples as suggested by Mohsenin (1986).

Selection of models

In order to interpret the results, modified Shedd equation (model-I), Hukill and Ives equation (model-II) and modified Ergun equation (model-III), were assessed for their fitness. The Shedd equation was used by many investigators to represent their airflow resistance data. The constant A of this equation takes into consideration factors such as shape, surface roughness of grain etc. which are difficult to measure. The Shedd equation can be rewritten by considering pressure drop as a function of airflow rate in the following form:

$$\Delta P = AV^B \tag{1}$$

Hukill and Ives (1955) proposed another equation to represent the Shedd data and also to take care of the non-linearity of experimental data on a log-log plot. This equation has been recommended by ASAE and proposed in ASAE standard D 272.3 which is in the following form.

$$\Delta P = \frac{AV^2}{\ln(1+BV)} \tag{2}$$

Modified form of Ergun equation was also selected on the basis of its merit as it is comparatively simpler in nature than other equations. It also takes into account the important factor of bed porosity which is the most important factor for airflow resistance in packed bed (McEwen *et al.* 1954).

$$\Delta P = AV \frac{(1-\varepsilon)^2}{\varepsilon^3} + BV^2 \frac{(1-\varepsilon)}{\varepsilon^3} \tag{3}$$

Experimental setup

The experimental airflow resistance data has been collected by using the same experimental setup as reported by Nimkar and Chattopadhyay (2003) and modified as described in succeeding paragraphs for lathyrus grain (Fig. 1). The airflow resistance apparatus consisted of components such as air-blow system, airflow measurement system, plenum chamber, test bin and pressure measurement system. A centrifugal blower (1), Wolf make, having air delivery capacity of 2.0 $m^3 min^{-1}$, was used to deliver air into an air duct. Air bypass (2) of 40 mm internal diameter (i.d.) with bend, tee and regulating valve (3) was provided to control the airflow rate. A polyvinyl chloride (PVC) pipe of 65 mm i.d. and 1735 mm long was provided as an air duct (4). A tap was provided to facilitate the airflow measurement in the air duct, having 1400 mm preceding and 325 mm succeeding air duct lengths in the direction of airflow. Airflow was measured with an electronic anemometer (5), ACD machine make, with ± 2% accuracy. Plenum chamber (6) consisted of three sections with volume of 0.091 m^3. The airflow straightener (7) was fabricated with 75 mm long, 10 mm i.d. aluminium tubing held together in a honeycomb configuration to diffuse vertical airflow uniformly. The vertical test bin (8) was constructed by rolling mild steel sheet (0.914 mm) into a cylinder of 210 mm diameter and 1150 mm long. Perforated floor for supporting the grain column was of stainless steel wire mesh having 2 mm square holes which was enough to prevent the grain from falling into the plenum chamber (Siebenmorgen and Jindal, 1987). The test bin was equipped with a rectangular discharge gate (9) of 100 by 75 mm size, with outlet chute to facilitate unloading of grain columns. The first set of three pressure taps (10) at an angle of 120° apart were located 60 mm above the perforated floor to facilitate smoother airflow near the beginning of grain bed. Subsequent pressure taps were provided at intervals of 200 mm along the test column. Pressure taps of 70 mm long copper tubes with 6 mm i.d. were introduced 35 mm inside the grain bed to reduce the wall effects on pressure drop measurement. Opening end of pressure tap in grain bed was covered with wire mesh to avoid entry of grain inside the tap.

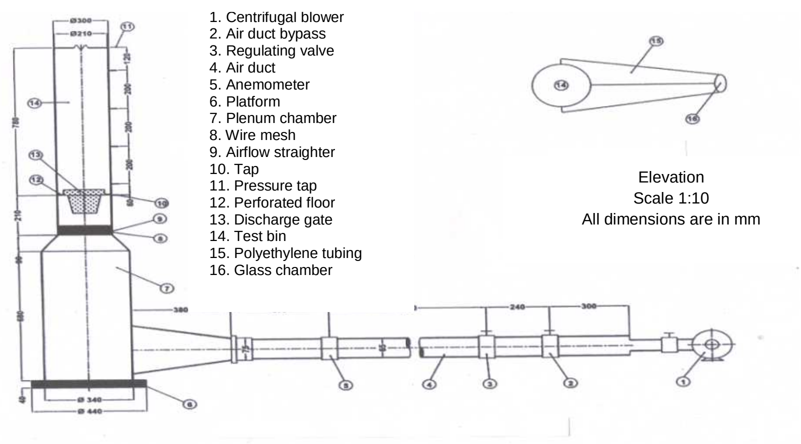

Fig. 1. Constructional details of the experimental setup

For static pressure measurement, three pressure taps at each level were connected to an inclined manometer, having the least count of 1 mm, by means of 6 mm diameter polyethylene tubing through flat bottom glass air the chamber so that pressure deviation at the section could be averaged. Kerosene of known density was used as the manometer fluid. The density values at different temperature of the manometer fluid (kerosene) were experimentally determined using standard procedure. The noted density values determined at the temperature of 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50^{o}C were found to be 819, 817, 815, 813, 810, 807, 802, 791, 787 and 783 kg m^{-3}, respectively. The setup could reproduce pressure drop observation with ± 5 Pa errors at the maximum airflow rate.

Experimental procedure

The conditioned test sample was removed from the refrigerator and left at room temperature for 6 h so as to equilibrate it with the ambient temperature before use. Test runs were carried out at three bulk densities obtained with loose, medium and densely packed grains and at this respective order. Firstly, the test bed was filled by the loose fill method as described by Shedd (1953). To obtain medium and dense packed bed conditions, initially a required quantity of test sample was loosely filled and then the bulk density was gradually increased to the desired level by tapping the side walls with a rubber hammer. After filling the test bin the top surface of the grain bed was levelled manually by using a stroker.

At each airflow rate, the test runs with five sets of observations were conducted at each bulk density level. The tests were carried out starting initially from the highest airflow rate and subsequently proceeding to the lowest airflow rate. The system was tested for air leakage at pressures up to 16 kPa using a soap solution at all joints before the start of each experiment. The velocity measurement was repeated after reloading of the grain bed for each replication. Relative humidity, atmospheric pressure and temperature were measured five times during each test run and the average values were used for airflow rate calculations to standard conditions of air temperature (31.5°C) and pressure (101.32 kPa). The temperature and relative humidity conditions recorded during the experiments for NLK-40, Pratik and Ratan were 32.5 ± 1.5°C and 64 ± 3%; 33.1 ± 2.0°C and 74 ± 5% and 36 ± 1.5°C and 77 ± 8%, respectively. The respective grain beds were at 13.10, 12.50 and 13.60% (d.b.) moisture content with bulk density of 805, 845, 895; 795, 835, 875 and 770,810, 850 kg m^{-3}. The pressure drops were measured at 0.2, 0.4 and 0.6 m bed depth. For NLK- 40, fifteen airflow rates ranged from 0.04 to 0.98 m^3 s^{-1} m^{-2}, for Pratik seventeen airflow rates ranged from 0.04 to 1.10 m^3 s^{-1} m^{-2} and for Ratan nineteen airflow rates ranged from 0.04 to 1.16 m^3 s^{-1} m^{-2}.

For fitting the experimental data to the selected models, the entire span of airflow rates was considered as a single continuous airflow range and sub-divided into three sub-ranges of airflows to obtain closer results. These partitions of three sub-ranges of airflows were based on physical observation of three straight line segments of different slopes obtained in the graphs plotted between airflow rate and pressure drop. These three sections represented low, medium and high ranges of airflows. The sub-ranges of airflows obtained for NLK-40 were $0.04 \leq V \leq 0.30$, $0.30 < V \leq 0.61$ and $0.61 < V \leq 0.98$ m^3 s^{-1} m^{-2}, for Pratik $0.04 \leq V \leq 0.30$, $0.30 < V \leq 0.69$ and $0.69 < V \leq 1.10$ m^3 s^{-1} m^{-2} and for Ratan $0.04 \leq V \leq 0.36$, $0.36 < V \leq 0.76$ and $0.76 < V \leq 1.16$ m^3 s^{-1} m^{-2}.The experimental data of lathyrus grain at each moisture and bulk density level were fitted to the selected three models by using non-linear least squares regression with MATLAB 7.1. Fitted parameters (constant A and B), coefficient of determination (R^2) and standard error of estimate (S_y) were used to compare the relative goodness of fitting the experimental data with these models. The standard error of estimate expressed the average deviation between experimental and predicted values. Acceptability of the models for predicting the pressure drop was decided on the basis of percent data falling in different ranges of standard error of estimate (Spiegel 1982).

RESULTS AND DISCUSSION

Characterisation of grains

The grain size (i.e. the cube root of the products of three axes of the grain), in-situ bulk density, true density and bulk porosity measured for the five representative samples are given in Table 1. The maximum variation of moisture content among the replicated samples was within 1.0%. The variations in bulk density and porosity values among triplicates were found to be negligible.

Table 1. Physical properties determined to characterise loose fill lathyrus grain beds

Grain	Moisture content % (d.b)	D_m (mm)	ρ_b (kg m^{-3})	ρ_t (kg m^{-3})	ε (%)
NLK- 40	13.10	4.47	805	1237	34.96
Pratik	12.50	5.03	795	1286	38.20
Ratan	13.60	5.22	770	1267	39.23

Mean values of five replications.

Fitting of pressure drop data

As regards the behaviour of the selected models for the purpose of fitting the experimental airflow resistance data of NLK- 40, it was observed (Tab. 2) that for the complete airflow range ($0.04 \leq V \leq 0.98$ m^3 s^{-1} m^{-2}) average values of standard error of estimate for the loose fill condition were 114.4, 96.38, 85.00 Pa m^{-1} with model I, II, III, respectively. For the sub-ranges of airflows of $0.04 \leq V \leq 0.30$, $0.30 < V \leq 0.61$ and $0.61 < V \leq 0.98$ m^3 s^{-1} m^{-2} the average standard error of estimate values for the loose fill conditions were 59.29, 70.01, 69.76; 39.65, 37.37, 34.83 and 18.17, 14.93, 12.48 Pa m^{-1}, respectively for model I, II and III. For Pratik beds it can be noted from Tab. 2 that for the complete airflow range ($0.04 \leq V \leq 1.10$ m^3 s^{-1} m^{-2}) average values of standard error of estimate for the loose fill condition were 105.5, 99.42, 100.6 Pa m^{-1} with model I, II, III, respectively. For sub-ranges of airflows of $0.04 \leq V \leq 0.30$, $0.30 < V \leq 0.69$ and $0.69 < V \leq 1.10$ $m^3 s^{-1} m^{-2}$ average standard error of estimate values for the loose fill conditions were found to be 40.76, 46.67, 46.57; 48.12, 47.23, 44.63 and 45.66, 50.98, 56.64 Pa m^{-1}, respectively for model I, II and III. In the case of Ratan variety it was observed (Tab 2) that for the complete airflow range ($0.04 \leq V \leq 1.16$ $m^3 s^{-1} m^{-2}$) average values of standard error of estimate for loose fill condition were 95.90, 98.00, 110.02 Pa m^{-1} with model I, II, III, respectively. For sub-ranges of airflows of $0.04 \leq V \leq 0.36$, $0.36 < V \leq 0.76$ and $0.76 < V \leq 1.16$ $m^3 s^{-1} m^{-2}$ the average standard error of estimate values for loose fill conditions were found to be 58.64, 51.38, 50.64; 46.56, 46.82, 48.53 and 30.26, 34.40, 39.46 Pa m^{-1}, respectively for model I, II and III. The pressure drop relationship with airflow rate for the loose fill condition is as shown in Figure 2.

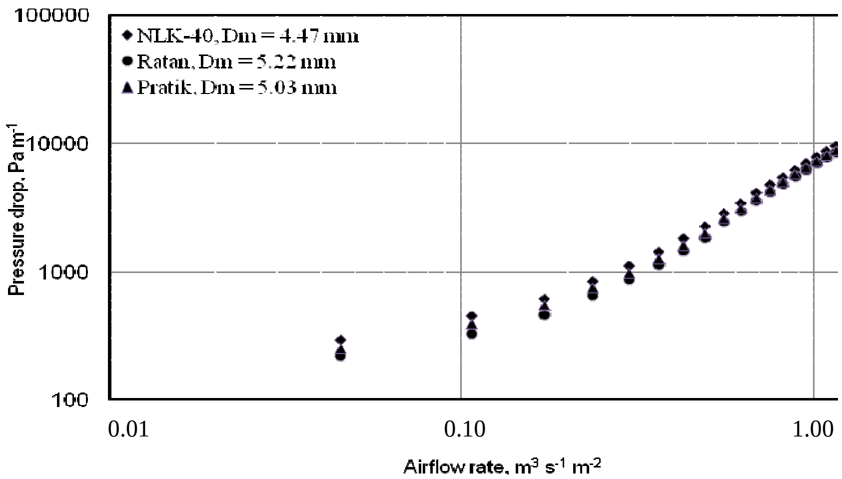

Fig. 2. Airflow and pressure drop relationship for lathyrus grain at loose fill condition

In general, while comparing for acceptability of these three models, the results indicated that for lathyrus grains 93% acceptable data sets were within 1 Sy limit and 7% in ± 2 Sy limit for model I. It was 74% in 1Sy limit; 15% in ± 2 Sy limit and 11% in ± 3 Sy limit for model II, whereas, these data sets were 56, 32 and 12% in 1Sy, ± 2 Sy and ± 3 Sy limit for model III. Hence, all these three models were acceptable for predicting pressure drop through lathyrus grains within the experimental airflow range of the study. This indicated that the modified Shedd equation is a better choice for predicting pressure drop through bulk lathyrus grains beds followed by the Hukill and Ives equation and the modified Erguns equation.

Table 2. Constants A and B in various models for complete range and three sub-ranges of airflows ($m^3 s^{-1} m^{-2}$) for various varieties of lathyrus

Grain/ model	A	B	R^2	Sy	A	B	R^2	Sy	A	B	R^2	Sy	A	B	R^2	Sy
NLK-40	$0.04 \le V \le 0.98$				$0.04 \le V \le 0.30$				$0.30 < V \le 0.61$				$0.61 < V \le 0.98$			
Modified Shedd	7405	1.619	0.997	114.4	2874	0.846	0.973	59.29	7367	1.654	0.998	39.65	7403	1.595	0.999	18.17
Hukill and Ives	18400	15.30	0.998	96.38	–2981	–0.755	0.963	70.01	25280	27.89	0.998	37.37	17610	9.747	0.999	14.93
Modified Ergun	206.6	359.2	0.999	85.00	401.6	–109.8	0.963	69.76	161.1	403.2	0.998	34.83	268.1	313.5	0.999	12.48
Pratik	$0.04 \le V \le 1.10$				$0.04 \le V \le 0.30$				$0.30 < V \le 0.69$				$0.69 < V \le 1.10$			
Modified Shedd	6866	1.670	0.998	105.5	2662	0.893	0.984	40.76	7253	1.806	0.998	48.12	6860	1.604	0.999	45.66
Hukill and Ives	21920	23.29	0.998	99.42	–1799	–0.541	0.979	46.67	41770	306.20	0.998	47.23	16140	9.523	0.999	50.98
Modified Ergun	251.9	465.46	0.998	100.6	487.45	–87.93	0.979	46.57	123.00	594.32	0.998	44.63	374.17	387.1	0.998	56.64
Ratan	$0.04 \le V \le 1.16$				$0.04 \le V \le 0.36$				$0.36 < V \le 0.76$				$0.76 < V \le 1.16$			
Modified Shedd	6525	1.709	0.999	95.90	3302	1.132	0.977	58.64	7111	1.915	0.998	46.56	6543	1.625	0.999	30.26
Hukill and Ives	23680	36.75	0.999	98.00	4362	1.98	0.982	51.38	83870	13340	0.998	46.82	16020	10.59	0.999	34.40
Modified Ergun	240.5	501.00	0.998	110.0	360.9	198.0	0.983	50.64	58.28	677.6	0.998	48.53	396.95	407.8	0.999	39.46

Mean values of five replications.

Similar results were reported for black gram (Nimkar and Mate 2004), moth gram, (Nimkar and Khobragade 2006), chickpea (Wilhelm *et al.* 2006; Masoumi and Tabil 2008) and for pistachio nuts (Kashaninejad and Tabil 2009).

Development of statistical model

The method of non-linear multiple regression analysis was used to describe the relationship between pressure drop across bulk lathyrus grain beds and airflow rate, bulk density and moisture content. Values of experimental pressure drop were regressed against each and all possible combinations of these variables in a stepwise approach. The model that was found to describe airflow resistance is as follows:

$$\Delta P = b_1V + b_2V^2 + b_3\, V\rho_b + b_4\, V\, M \qquad (4)$$

This form of equation allowed relative comparison of each of the variable effects. Velocity was included as an overall multiplier to ensure that the model could not predict a pressure drop at zero airflow rates. Since drag is the function of velocity squared, the addition of airflow rate as an overall multiplier in the statistical model better approximates airflow resistance theory (Siebenmorgen and Jindal 1987). It was found that all the model variables of Eq. 4 improved the model sufficiently to ensure inclusion in the model at 1% level of significance

It was observed from Table 3 that for predicting pressure drop through NLK-40 with the statistical model (Eq. 4), the values of the coefficient of determination for complete, low, medium and high airflow ranges were 0.994, 0.989, 0.994 and 0.9881, respectively for 600 mm bed depth. In all cases the percent data were more than 96% in $\pm$2 Sy limit. The statistical model could predict pressure drop in the full airflow range ($0.04 \leq V \leq 0.98$ m^3 s^{-1} m^{-2}) with standard error of estimate of 249.9 Pa m^{-1}, whereas, for the values of standard error of estimate for the sub-ranges of $0.04 \leq V \leq 0.30$, $0.30 < V \leq 0.61$ and $0.61 < V \leq 0.98$ m^3 s^{-1} m^{-2} were 45.66, 87.34 and 250.2 Pa m^{-1}, respectively. For predicting pressure drop through Pratik beds with the model the values of coefficient of determination for complete, low, medium and high airflow ranges were 0.997, 0.996, 0.995 and 0.997 for 600 mm bed depth, respectively. In all cases the percent data were more than 97% in $\pm$2 Sy limit. The model could predict pressure drop in the full airflow range ($0.04 \leq V \leq 1.10$ m^3 s^{-1} m^{-2}) with standard error of estimate of 172.3 Pa m^{-1}**,** whereas, the values of standard error of estimate for the sub-ranges $0.04 \leq V \leq 0.30$, $0.30 < V \leq 0.69$ and $0.69 < V \leq 1.10$ m^3 s^{-1} m^{-2} were 22.24, 86.71 and 105.9 Pa m^{-1}, respectively. In the case of Ratan with the model the values of coefficient of determination for complete, low, medium and high airflow ranges were 0.9941, 0.9923, 0.9659 and 0.9860, respectively. In all cases the percent data were more than 98% in $\pm$2 Sy limit. The model could predict pressure drop in the full airflow range ($0.04 \leq V \leq 1.16$ m^3 s^{-1} m^{-2}) with standard error of estimate of 247.1 Pa m^{-1}, whereas, the values of standard error of estimate for the sub-ranges $0.04 \leq V \leq 0.36$, $0.36 < V \leq 0.76$ and $0.76 < V \leq 1.16$ m^3 s^{-1} m^{-2} were 37.75, 211.1 and 242.2 Pa m^{-1}, respectively.

Table 3. Coefficient of estimated multiple regression model (Eq. 4) to describe the airflow resistance of lathyrus grain. M = Moisture content, BD = Bulk density and ε = bed porosity.

Variety/airflow range (m^3 s^{-1} m^{-2})	Regression coefficients				R^2	Sy
	b_1	b_2	b_3	b_4		
NLK– 40	M = 7.33-8.80% (d.b.), BD = 790-910 kg m^{-3} and ε = 24.84-35.57%					
$0.04 \leq V \leq 0.98$	–41248	8697	47.69	155.38	0.9936	249.9
$0.04 \leq V \leq 0.30$	–18602	8016	22.77	50.12	0.9889	45.66
$0.30 < V \leq 0.61$	–32044	11115	34.73	105.40	0.9944	87.34
$0.61 < V \leq 0.98$	–31697	–881.06	53.91	178.26	0.9881	250.2
Pratik	M = 6.75-18.30% (d. b.), BD = 760-905 kg m^{-3} and ε = 31.68-37.69%					
$0.04 \leq V \leq 1.10$	–27032	6218	32.51	157.20	0.9969	172.3
$0.04 \leq V \leq 0.30$	–13062	5621	16.65	61.27	0.9961	22.24
$0.30 < V \leq 0.69$	–24907	10758	25.68	124.99	0.9949	86.71
$0.69 < V \leq 1.10$	–22150	1558	35.52	171.91	0.9970	105.9
Ratan	M = 7.90-19.40% (d. b.), BD = 755-890 kg m^{-3} and ε = 30.34-39.23%					
$0.04 \leq V \leq 1.16$	–212444	5205	27.56	95.76	0.9941	247.1
$0.04 \leq V \leq 0.36$	–11074	6747	13.85	36.48	0.9923	37.75
$0.36 < V \leq 0.76$	–14263	1183	26.32	101.15	0.9659	211.1
$0.76 < V \leq 1.16$	–9155	–2106	28.97	98.36	0.9860	242.2

CONCLUSIONS

From the study undertaken the following specific conclusions could be drawn:

1. All the selected models were accurate enough for predicting pressure drop through lathyrus grain beds within the experimental range under study. However, the modified Shedd equation was more precise for predicting pressure drop based on statistical analysis, followed by Hukill and Ives and Modified Ergun equation.

2. Coefficient A of modified Shedd equation was linearly related to the grain moisture content and it represented the change in moisture content for the selected lathyrus varieties.

3. The statistical model developed for predicting pressure drop through bulk lathyrus as affected by airflow rate, bulk density and moisture content was found to fit the experimental data reasonably well.

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OPÓR AERODYNAMICZNY ZIARNA LĘDŹWIANU SIEWNEGO

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S t r e s z c z e n i e. Badania przeprowadzono w celu określenia oporu aerodynamicznego ziarna lędźwianu siewnego. Materiał do badań otrzymano z gospodarstwa uniwersyteckiego. Opór aerodynamiczny trzech odmian lędźwianu siewnego (cv. NLK-40, Pratik i Ratan) badano za pomocą aparatury laboratoryjnej przy wilgotności ziarna od 7,33 do 18,80, 6,75 do 18,30 i 7,90 do 19,40% (s. m.), dla prędkości przepływu powietrza w zakresie od 0,04 do 1.26, 0,04 do 1,40 oraz 0,04 do 1,48 $m^3 \cdot s^{-1} \cdot m^{-2}$, przy grubości warstwy ziarna od 0,2 do 0,6 m i gęstości usypowej ziarna w zakresach od 805 do 895, 795 do 875 oraz 770 do 850 $kg \cdot m^{-3}$. Opór aerodynamiczny ziarna lędźwianu wzrastał ze wzrostem przepływu powietrza, gęstością, głębokością w warstwie, a zmniejszał się ze wzrostem wilgotności. Przeanalizowano zmodyfikowane równanie Shedd'a, równanie Hukilla oraz Ives's, a także zmodyfikowane równanie Erguns'a pod kątem ich przydatności do prognozowania spadku ciśnienia. Opór aerodynamiczny ziarna lędźwianu był poprawnie opisywany przez zmodyfikowane równanie Shedd'a, a w dalszej kolejności przez równanie Hukilla i Ivesa oraz zmodyfikowane równanie Erguns'a. Opracowany model statystyczny, obejmujący prędkość przepływu powietrza, wilgotność ziarna oraz jego gęstość usypową, charakteryzował się dość dobrym dopasowaniem danych dotyczących spadku ciśnienia.

S ł o w a k l u c z o w e: opór aerodynamiczny, spadek ciśnienia, lędźwian siewny