Journal of Agrometeorology 20 (2) : 122-125 (June 2018)

Aerodynamic properties of green gram sown in different environments in Indo-Gangetic Plains of West Bengal

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ABSTRACT

Field experiments were conducted on green gram during spring-summer seasons of 2011 and 2012 with four dates of sowing and five varieties arranged in a strip-plot design to study the aerodynamic characteristics of green gram at BCKV, Kalyani, West Bengal. Micro-cup anemometers were placed at 0.5, 1.0, 1.5, 2.0 and 2.5 m above the crop canopy on a wooden mast. The zero-plane displacement (d), roughness length (Z_0) and drag coefficient (C_d) were found to increase with crop age but the effect of dates of sowing was not prominent except at the final stage of growth. For a LAI value of 1.5, "d" values was 0.254 m and the "C_d" value was 0.015. Both the "C_d" and "d" increased with plant height and LAI. The "d" and "Z_0" had significant positive correlation with the total dry matter and crop growth rate irrespective of dates of sowing.

Key Words *:* Dates of sowing, drag coefficient, green gram, roughness length, zero-plane displacement

The growth and productivity of crops are determined by growing environment in which maintenance of equilibrium between the vegetation and surrounding air is of utmost importance. Aerodynamic properties *viz.* zero-plane displacement (d), roughness length, friction velocity, drag coefficient have a profound impact on growth of the crop (Dong *et al*., 2001). The crop canopy behaves as a rough surface and it determines the shape of the wind profile above the crop. In case of natural turbulent boundary layer, where the temperature gradient is small and having uniform density, the wind profile follows a log law (Dong *et al*., 2001). The leaf area index, leaf area distribution affect the drag coefficient of different crops (Kitagawa *et al*., 2015). Masseroni *et al*. (2015) observed a close correlation between the height of the rice crop with "d" and "Z_0". The roughness length (Z_0) or displacement height (d) computed from the observed wind profile have been utilized to evaluate the effects of vegetation on wind erosion (Abtew *et al*., 1989; Lee, 1991). A large number of studies have been reported on two major roughness parameters over a crop surface and these are zero-plane displacement (d) and roughness length (Z_0). Kumar *et al*. (2001) studied the interdepencence of various aerodynamic parameters viz. roughness length, drag coefficients and frictional velocity at Anand under different stability conditions. Chakraborty *et al*. (2012) observed that high wind speed increased the friction velocity and reduced "d" in wheat crop. In the present experiment, we have studied the important aerodynamic properties and their impact on growth of greengram crop sown under different dates.

MATERIALS AND METHODS

Experiment details

The experiment was carried out during spring-summer seasons (SMW from 7 to 21) of 2011 and 2012 at the District Seed Farm, BCKV, Kalyani, West Bengal, India. The site is located at 22°56′ N latitude and 88°32′E longitude at an altitude of 9.75 m above MSL. The soil is sandy-loam in texture with almost neutral pH (7.1). The soil contains 0.54 per cent organic carbon, 0.053 per cent total N, 19.72 kg ha^{-1} available P_2O_5 and 218.96 kg ha^{-1} available K_2O obtained from the soil analysis of the experimental field.

The experiment was carried out in a strip-plot design where four dates of sowing (DOS) (D_1-15th February, D_2-25th February, D_3-7th March and D_4-17th March) were placed in the horizontal strips and five varieties (V_1- IPM 2-3, V_2- *Samrat*, V_3- Pant Mung-5, V_4- *Sonali* and V_5- *Meha*) were placed in vertical strips. However, for the measurement of wind speed influence of varieties were ignored.

Instrumentation

Each dates of sowing represents horizontal strips. Each horizontal strip has 20 m open air space around it in the

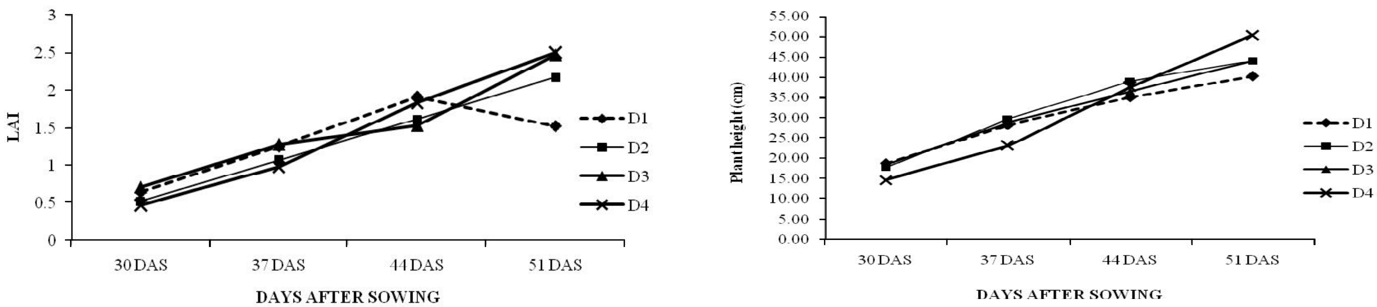

Fig. 1: Changes in crop height and LAI in green gram under different dates of sowing (pooled mean over two years)

field so that there was no hindrance in wind flow. A 5 m tall wooden mast with fittings at different heights was placed in the middle of the strip representing dates of sowing. Micro-anemometers (MODEL: OC Anemo-01) were placed at 0.5, 1.0, 1.5, 2.0 and 2.5 m above the crop canopy. Cup type anemometer is used as sensor and sensing is done by optical sensor and chopper wheel. The starting threshold of the anemometer is less than 0.3 ms^{-1}, range is 0 – 60 ms^{-1}; radius of the cup is 0.025 m, radius of the assembly is 0.11 m and the height is 0.16 m. The cup material is stainless steel.

Aerodynamic computation

The zero plane displacement (d) was computed following Thom (1971);

$$d= 0.75h,$$

where "h" is the mean canopy height in meter.

The roughness length (Z_0) was computed by the formulae used by Chamberlain (1968),

$$Z_0 = 0.125h,$$

where "h" is the mean canopy height.

The drag coefficient "C_d" was estimated by the formulae described by Dong *et al.* (2001),

$C_d = (U_*/U)^2$, where U_* is friction velocity, U is mean wind velocity at Z height. The U* is computed by the formulae $U = U_*/K\,[\ln\{(Z-d)/Z_0\}]$ where K is von Karman's constant (0.41).

The observations were recorded from 30 days after sowing (DAS) to 51 DAS of the crop at a 7 days interval. The mean canopy height was recorded from the middle row from 10 pre-selected plants. The LAI was calculated following Radford (1967). The total dry matter (TDM) and crop growth rate (CGR) were computed for correlating these with aerodynamic properties. The wind speed was recorded at 8, 12 and 16 hour and the data were averaged for a particular date of observation. For measurement of wind speed each anemometer was allowed to run for 15 minutes and data were collected from this duration with the help of a data logger (Model: FDB MK IV).

Relevant relationships were statistically analyzed following SPSS 7.5 software (SPSS 7.5, copyright 1997 by SPSS Inc, USA, Base 7.5 Application guide) obtained from University.

RESULTS AND DISCUSSION

Plant height and leaf area index (LAI)

The plant height recorded a gradual increase from 30 – 51 DAS irrespective of dates of sowing (Fig 1). The rate of increment was maximum under D_4 sowing because of the increased temperature to which the crop was exposed. The LAI also increased but a decline was noted in case of D_1 sown crop after 44 DAS. The early sown crop recorded yellowing of leaves at the later phase of growth thus reducing the LAI values (Fig 1).

Drag coefficient

The drag coefficient (C_d) increased gradually with the advancement of crop growth. During initial phase, there is no regular trend in "C_d" with the delay in sowing, however at the final stage the "C_d" increased gradually with the delay in sowing. The increment in "C_d" was observed due to increased height and LAI of the crop. The "C_d" increased logarithmically with the plant height (Fig 2). The relationship was highly significant; 97.1 per cent variation in "C_d" was explained by the variation in plant height. For the crop height of 0.4 m the "C_d" value was 0.039. Dong *et al*. (2001) reported an increased "C_d" with the height of the hypothetical standing vegetation. The "C_d" increased logarithmically with LAI (Fig 3). The R^2 value remained very high (0.848) indicating the closeness of the association between these two parameters. For the LAI value 1.5, the "C_d" value was 0.015. This increment of "C_d" with LAI was due to clumping character of the green gram canopy (Kitagawa *et al*., 2015).

Table 1: Relationship of zero-plane displacement (d) and roughness length (Z_0) with total dry matter (TDM, gm^{-2}) and crop growth rate (CGR, $gm^{-2}day^{-1}$) in green gram (pooled over dates of observation and experimental years).

Parameters	Correlation coefficient (r)
"d" and TDM	0.934**
"d" and CGR	0.864**
"Z_0" and TDM	0.932**
"Z_0" and CGR	0.864**

** Correlation is significant at 0.01 levels; No. of observations 32

Zero-plane displacement

The mean zero-plane displacement (d) increased gradually with the advancement of growth irrespective of dates of sowing and experimental years, although the "d" values were different in two different years. The "d" values' were not influenced by the variation in dates of sowing. The "d" increased significantly with the LAI of the crop. The "d" value was found to be the polynomial function of LAI. When LAI was 1.5, the "d" value was 0.254 m (Fig 4). The "d" values' dependence on wind speed is largely affected by the LAI and the drag coefficient of individual leaf. The "d" value increased with growth because of increased height and LAI (Dong *et al.*, 2001).The"d" was strongly correlated to both the TDM and CGR (Table 1). The correlation coefficients ranged from 0.934 in case of TDM and 0.864 in case of CGR. Masseroni *et al.* (2015) observed that the values of "d" and "Z_0" were positively correlated with the height of the rice crop.

Roughness length

The roughness parameter is a measure of aerodynamic roughness of the crop over which the wind speed profile is measured.It may be used to evaluate the disturbance of vegetation to the near surface air flow (Abtew *et al.*, 1989). The values of "Z_0" increased with the progress of growth. The "Z_0" was strongly correlated to the TDM and CGR (Table 1).The correlation coefficients were 0.932 and 0.864 respectively for "Z_0" with TDM and CGR of the crop.Dong *et al*. (2001) reported a very good correlation (0.96 – 0.99) among "Z_0", vegetation density and crop height. Increase in "Z_0" due to increase in roughness of the crop surface because of increased LAI, height, initiation of flower and pods in the plant (Masseroni *et al.,* 2015).

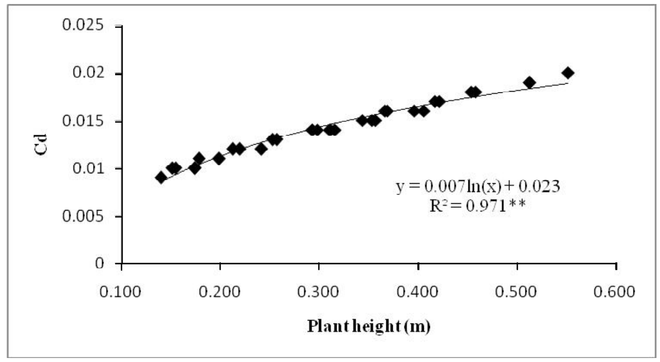

Fig.2: Changes in C_d with the changing height of the greengram (pooled over dates of sowing and experimental years)

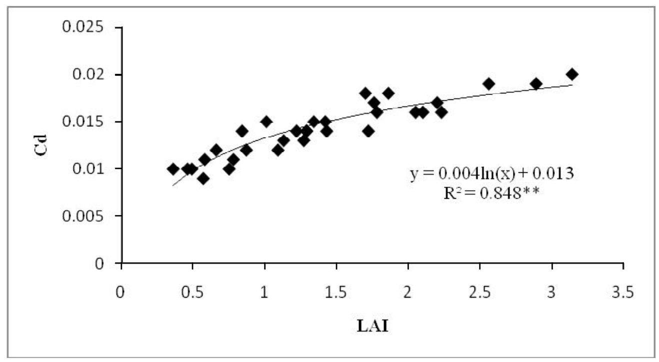

Fig.3: Changes in C_d with the changing LAI of the green gram (pooled over dates of sowing and experimental years).

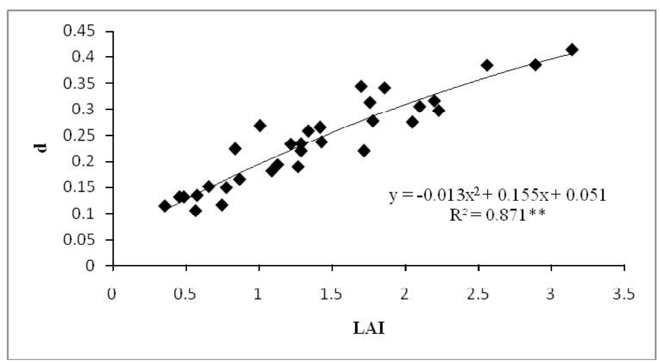

Fig. 4: Changes in zero-plane displacement (d) with LAI of greengram (pooled over dates of sowing and experimental years)

CONCLUSION

The "d" and "Z_0" were positively and significantly correlated to TDM and CGR of the crop. The "d" and "C_d" increased with the crop age, height and LAI.

ACKNOWLEDGEMENT

The first author acknowledges Department of Science and Technology, Government of India for providing the fund through INSPIRE Fellowship to carry out the research programme.

REFERENCES

Abtew,W., Gregory, J.M. and Borreli, J. (1989). Wind profile: estimation of displacement height and aerodynamic roughness. *Trans ASAE.,* 32: 521-527.

Chakraborty, P.K., Biswas, M., Dutta, S.K. and Jena. S. (2012). Aerodynamic properties and its relationship with height and leaf area index of seasame crop. *J. Agrometeorol.,* 14(Special Issue): 233-237.

Chamberlain, A.C. (1968). Transport of gases to and from surfaces with bluff and wave like roughness elements. *Q. J. Royal Meteorol. Soc.,* 94: 318-332.

Dong, Z., Gao, S. and Fryrear, D.W. (2001). Drag coefficients, roughness length and zero-plane displacement height as disturbed by artificial standing vegetation. *J. Arid Environ.,*49: 485-505.

Kitagawa, K., Iwama, S., Fukui, S., Sunaoka, Y., Yazawa, H., Usami, A., Naramoto, M., Uchida, T., Saito, S. and Mizunaga, H. (2015). Effects of components of the leaf area distribution on drag relations for *Cryptomeria japonica* and *Chamaecyparis obtuse. Eur. J. For. Res.*, 134: 403-414.

Kumar, M., Gupta, B. R. D., Pandey, V., Shekh, A. M. and Parmar, R. S. (2001). Roughness length and drag coefficient at Anand. *J. Agrometeorol.,* 3(1 & 2): 261-266.

Lee, J.A. (1991). Near surface wind flow around desert shrubs. *Physical Geography,* 12: 140-146.

Masseroni, D., Facchi, A. and Gandolfi, C. (2015). Estimation of zero-plane displacement height and aerodynamic roughness length on rice fields. *Ital.J. Agrometeorol.*, 20 (1): 67-76.

Radford, P.J. (1967). Growth analysis formulae – their use and abuse. *Crop Sci.*, 7: 171-175.

Thom, A.S. (1971). Momentum absorption by vegetation. *Q. J. Royal Meteorol. Soc.,* 97:414-428.

Received : November 2017 ; Accepted : April 2018