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Nature and shape of wind profile over the mungbean canopy sown under different dates and its impact on biological parameters in the tropical sub-humid environment

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ABSTRACT

A two year experiment on four mungbean varieties sown on three different dates has been conducted at the BCKV research farm (22°56' N latitude, 88°32' E longitude). The wind speed at 11:30 h at the initial phase was higher under 15th February and 1st March sowings but the later phase recorded higher wind speed in case of 15th March sowing. The later phase recorded higher wind speed at 15:30 hour irrespective of dates of sowing. Wind speed over the crop was maximum when the leaf area index (LAI) was approximately 0.50. Dry matter accumulation and plant height significantly reduced the wind speed over the crop canopy. Wind speed declined when the LAI exceeded 1.15 under 15th February and 1st March sowings and 1.75 under 15th March sowing. Height over 40.8cm reduced the wind speed of late sown crops. Biological parameters were found to be the polynomial functions of wind speed.

***Keywords*:** Dry matter accumulation, LAI, mungbean and wind profile

Mungbean (*Vigna radiata*) is originated in India (Reddy, 2004) and has been grown in India since ancient times. It is widely grown in South-East Asia, Africa, South America and Australia. In India, mungbeans are grown in all the states except the hilly regions. It is usually grown during January to May and July to September in the Gangetic plains of West Bengal under medium land situation. The seed is used as edible pulses. The growth and productivity of pulses widely vary because of weather parameters, particularly radiation, rainfall, temperature and wind speed over the crop canopy. High wind increases the friction velocity on the one hand, diminishes the depth of zero-plane displacement (Chakraborty *et al.*, 2012).

Wind speed increases above the crop logarithmically following a log law. The vegetation makes the shape of the profile complex. The velocity profiles over the vegetative surface maybe described as discontinuous functions (Dong *et al*., 2001). Wind speed over the crop canopy and its profile character determine the rate of transpiration, stomatal diffusion resistance and leaf temperature which regulate the biomass accumulation in different plant parts (Chakraborty *et al*., 1991; Chakraborty, 1994). During the vegetative and reproductive phases, the impact of wind profile on crop is different. During the early phase of growth, high wind speed maybe beneficial because of higher transpiration rate, lower stomatal diffusion resistance and leaf temperature (Jena, 2011). At the later phase, the increased wind speed may disturb the pollination process resulting in lower pod formation and seed yield in legumes. High wind speed may also cause turbulence leading to the uneven temperature distribution in the mesophyll cells and concomitant reduction in photosynthesis (Thorpe and Butler, 1977). Therefore, it is important to measure the wind profile and its characteristics over the crop canopy.

The mungbean is an important *pre-kharif* crop which is sown during a span of January to March in the Gangetic plains of West Bengal. The different phases of this crop are subjected to the variation in wind speed throughout its lifecycle. Agronomically, the optimum date of sowing for this crop has been demarcated (Rahman *et al.*, 2002; Siddique *et al.*, 2004; Bhowmick *et al.*, 2008). However, the impact of weather parameter on this important crop is not well studied. As the crop has to pass its lifecycle within a particular atmospheric specification, it is important to study the impact of weather parameter on the crop to demarcate its growing season properly. The impact of radiation on the growth of pulse has been studied by several authors (Board, 2004; Jena *et al.*, 2010). However, no such information is available on the characteristics of wind profile over the mungbean canopy in the Gangetic plains of West Bengal. To address these lacunae, the present experiment is designed to study the nature of wind profile over the mungbean crop and its impact on crop growth processes in mungbean crop.

MATERIALS AND METHODS

The experiment was undertaken during summer (*pre-kharif*) seasons of 2010 and 2011 at Jaguli Instructional Farm (New Alluvial zone),

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Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India (22°56' N latitude, 88°32' E longitude and at an altitude of 9.75 m above mean sea level). The soil was sandy loam with good drainage facility and neutral in reaction. Composite soil samples from 0-30 cm depth were taken from the experimental field for analysis of the physico-chemical properties of the soil. The soil contained 6.40% coarse sand, 40.00% fine sand, 32.80% silt, 19.94% clay, 0.58% organic carbon, 0.06% total nitrogen, 22.90 Kg ha^{-1} available phosphorus, 136.66 Kg ha^{-1} available potassium and had a soil pH of 6.8. The experiment was laid out in a split-plot design with three replications. The main plot consisted of three dates of sowing (D_1-15th February, D_2-1st March and D_3-15th March) and the sub-plot comprised of four varieties of mungbean (V_1-Pant Mung-5, V_2-Bireswar, V_3-RMG-62 and V_4-Sukumar) which were allotted to plots of 5 m x 6 m area.

Sowing of each variety was done at an interval of fifteen days and the seed rate was 25 kg ha^{-1} while maintaining row to row distance of 25 cm and plant to plant distance of 10 cm. Before sowing, the seeds were treated with *Rhizobium* culture at the rate of 4 g kg^{-1} seed. Fully decomposed farm yard manure (FYM, decomposed organic matter prepared from cowdung) at the rate of 5 t ha^{-1} was applied at the time of final land preparation and a general dose of 20 kg ha^{-1} nitrogen through Urea, 40 kg ha^{-1} P_2O_5 through Single Super Phosphate and 40 kg ha^{-1} K_2O through Muriate of Potash were applied as basal.

Five plants were selected at random for the measurement of height. The canopy height of the plant from ground level to the highest point of the plant was measured with a meter scale and the mean value were calculated for each plant plot wise after 25 DAE at seven days interval. At the same time, two plants were collected from each plot at an interval of 7 days starting from 25 days after emergence (DAE). The leaves, stems and root were separated and dried in hot air oven at 75°C temperature for 48 hours. The summation of the dry weight of stem, leaves and root gave total dry matter accumulation which was then calculated in terms of g m^{-2}. The dry weights of the green laminas recorded were used to calculate the leaf area index as follows (Radford, 1967)

$$\text{LAI} = \frac{\text{Total leaf area for a given land area } (m^2)}{\text{Land area considered } (m^2)}$$

A wooden mast (pole) was placed in the middle of the experimental field and the anemometers were fixed at the desired height to measure the speed. Byram's micro anemometer was used to measure the wind speed at 50, 100 and 150 cm above the crop. Wind speed was recorded at 7:30, 11:30 and 15:30 hours on each day at seven days interval during 25 DAE to pod development. Wind speed above the crop was measured under open condition only.

The wind profile equation can be described as:

$$u(z) = u_*/k. [\ln \{ (z-d)/z_o\}]$$

Where,

$u(z)$ = The mean wind speed at height z

k = Von Karman's constant (0.41)

u_* = Friction velocity

z_o = Roughness parameter

d = Zeroplane displacement

(Each valid for $z \geq h$ only, h = crop height)

The relationships between wind speed and plant parameters were worked out.

RESULTS AND DISCUSSION

The diurnal variation in wind profile during the progress of crop growth has been presented in Fig. 1. The 15th February and 1st March sown crop recorded high wind speed during the initial phase. Higher wind speed was recorded in 2011 in comparison to 2010. During the early phase of crop, the crop height remained low and this did not disturb the wind flow 1.5 m above the crop height effectively because the drag was low (Legg *et al.*, 1981; Jena, 2011). At 11:30 hour, the initial phase recorded higher wind speed under 15th February and 1st March sowing, whereas under 15th March sowing, the later phase of growth recorded higher wind speed at 150 cm above the crop. At 15:30 hour, the crop was exposed to higher wind speed during the later phase of growth irrespective of date of sowing (Fig. 1). The high wind speed during the later phase of growth might have increased the rate of transpiration, a concomitant desiccation of floral parts might also develop which might increase the fall of bud and flower leading to the low pod yield (Tzudir, 2012).

The wind profile over the mungbean canopy pooled over time, dates of sowing and year showed that the wind speed increased with the anemometer height logarithmically following standard log equation, although the shape of the curve was not similar to other workers (Legg *et al.*, 1981; Monteith and Unsworth, 2001; Dong *et al.*, 2001). The strength of association was highest on 39 DAE; 82.7% variation in wind speed was explained by the variation in height on 39 DAE. The strength of association was the lowest on 46 DAE (Fig. 2).

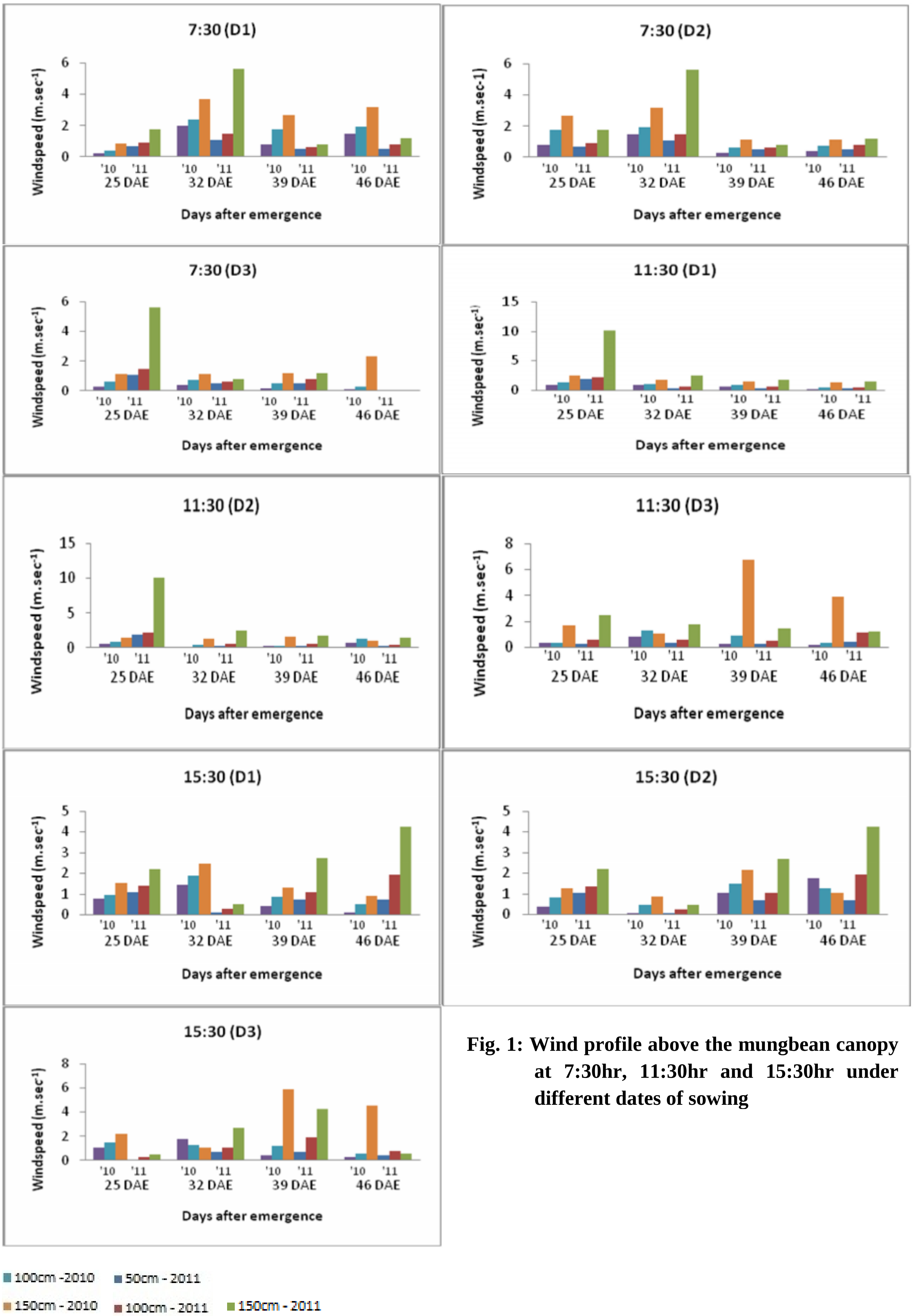

Fig. 1: Wind profile above the mungbean canopy at 7:30hr, 11:30hr and 15:30hr under different dates of sowing

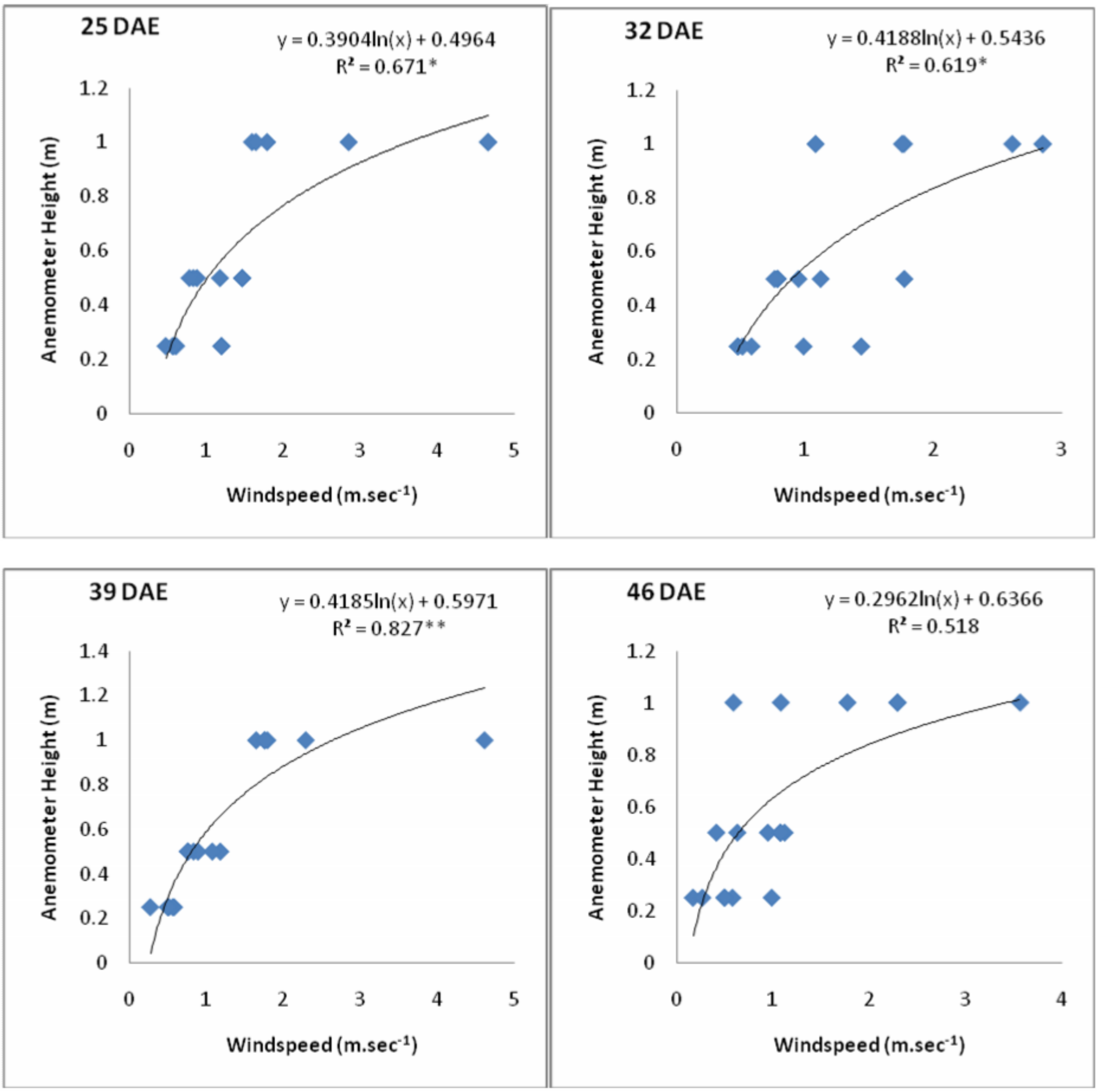

Fig. 2: The shape of wind profile over the mungbean crop during the progress of growth (Pooled over time, dates of sowing and year)

The wind speed decreased with the growth of the crop i.e., with the increment of the LAI under 15th February, 1st March and 15th March sowing. The point of intersection appeared on 38th DAE on 15th February, 34th DAE on 1st March and 41st DAE on 15th March. Under 15th February and 1st March sowing, wind speed declined when the LAI values were 1.15 and 1.15 respectively but under 15th March sowing, the wind speed declined when the LAI exceeded 1.75. This happened due to low vegetative growth under 15th March sowing. The relationship between the wind speed and dry matter also recorded the similar trend (Fig. 3). Under 15th February sowing, wind speed declined beyond 37 DAE when the plant height was 24.4 cm, whereas under 1st March sowing, wind speed declined 34 DAE onwards when the crop height was 30.2 cm. In case of 15th March sowing, wind speed sharply declined when the crop height exceeded 40.8 cm (Fig. 3). Reduction in wind speed beyond certain specific height, LAI or the crop biomass (dry matter) was due to increment of drag coefficient. The drag coefficient has a tendency to increase with the increasing height of the vegetation but the rate of increase reduces with the increased population density. Dong *et al* (2001) observed a linear and significant relationship between the drag coefficient and crop height. Legg *et al* (1981) observed that the drag coefficient remained constant for most of the season in case of bean or potato crop. Jena (2011) observed that the drag coefficient increased polynomially with the increment in height in case of sole wheat and mustard. The increase in the drag coefficient has an enormous importance in the mass and momentum transfer within the canopy i.e., exchanges of carbon dioxide, oxygen and water vapour in-between the canopy and surrounding air.

The plant height, dry matter accumulation and LAI recorded a significant relationship with the wind speed over the mungbean canopy. The LAI, dry matter and plant height were found to be the polynomial function of wind speed. The leaf area index, dry matter accumulation and the plant height had an inverse relationship with the wind speed i.e., at lower wind speed all the plant parameters were high. The coefficient of determination (R^2 values) remained always higher than 0.9 indicating the strength of the relationship (Fig. 4).

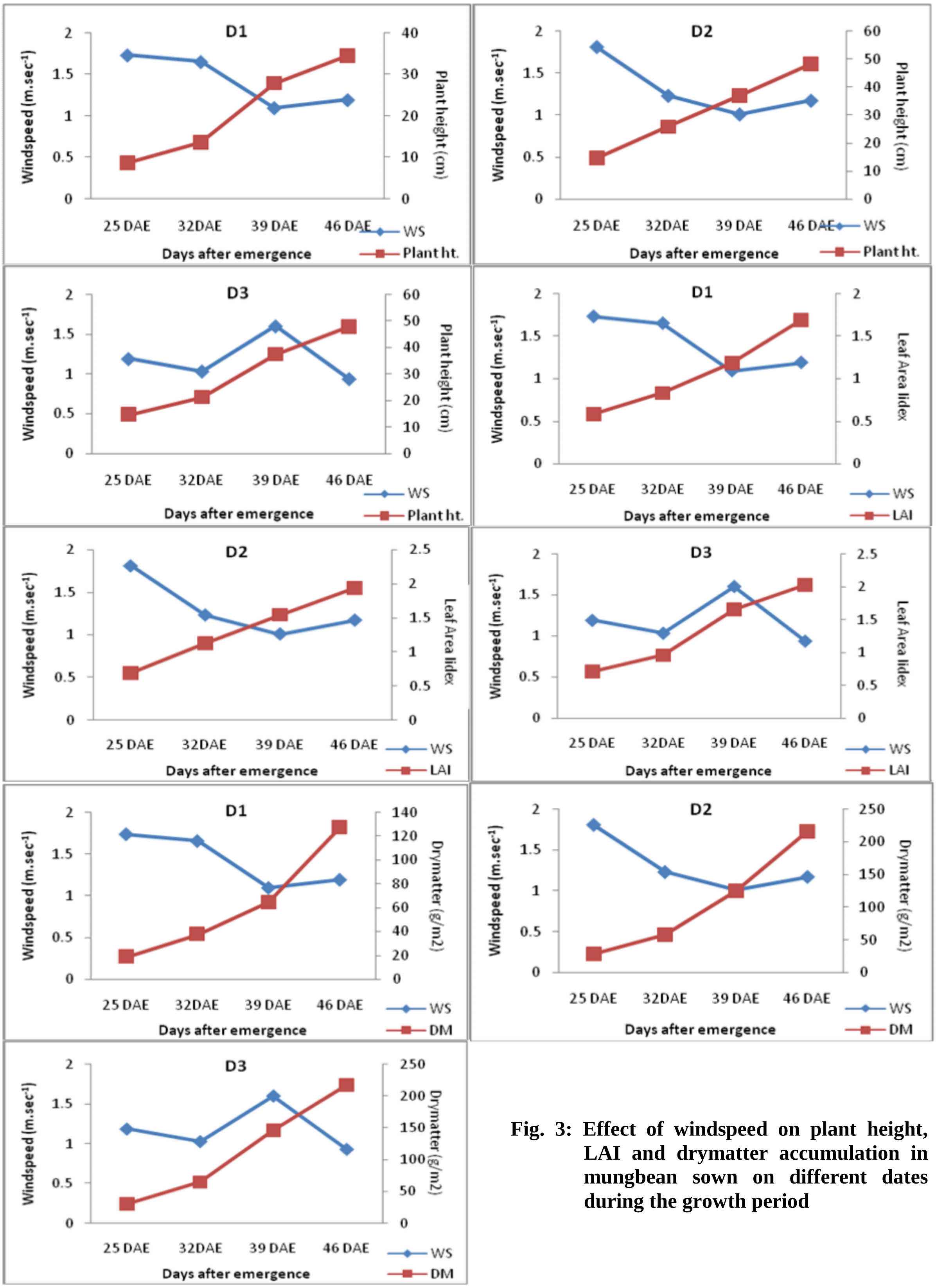

Fig. 3: Effect of windspeed on plant height, LAI and drymatter accumulation in mungbean sown on different dates during the growth period

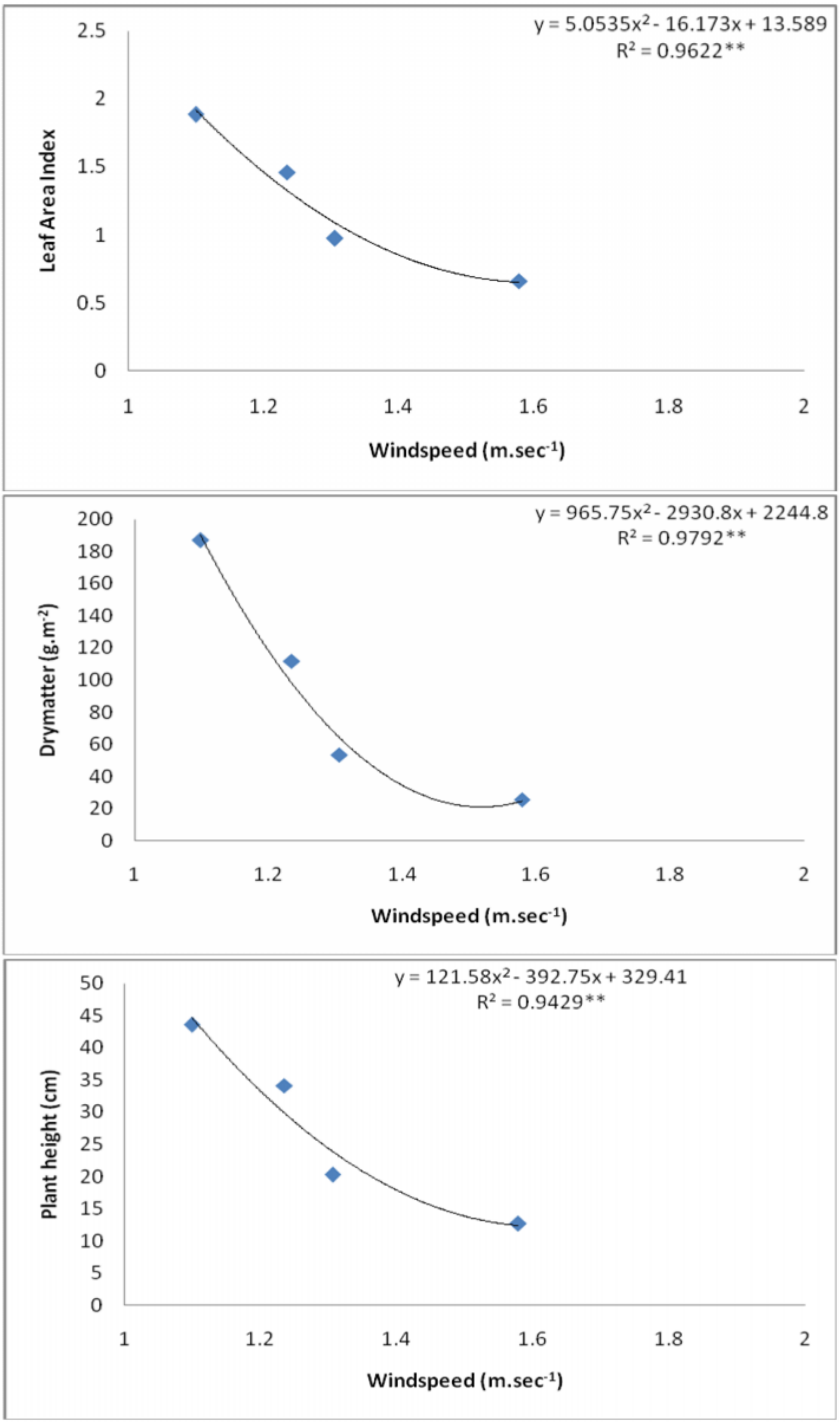

Fig. 4: Relationship between windspeed and biological parameters in mungbean crop

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