MICROMETEOROLOGY IN PADDY FIELD AND ITS APPLICATION TO ESTIMATION OF SPRAY DRIFT

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ABSTRACT

Chemical application, one of the most important crop management processes happened to cause spray drift, that would threaten farmers in field as well as dwellers in rural region.

Spray drift was affected by micro-meteorological parameters. In Korea, a boom sprayer was introduced but good effects of a boom sprayer was not evaluated. A study to evaluate short distance drift characteristics of a boom sprayer in paddy fields has been undergoing and determining wind characteristics in paddy field was the main purpose of this paper.

Micro-meteorological information has been pre-requisite information for evaluating drift in both long and short distances or in both theoretical and experimental ways. Wind velocity, Reynolds stresses, turbulence intensity, skewness, kurtosis etc. were evaluated with height from the ground using a 2-dimensional probe and a hot wire anemometer system.

Key words : turbulence, micro-meteorology, paddy, spray, drift

INTRODUCTION

There were many scientific approaches in evaluation long distance air pollutant transport. Spray drift could be interpreted as an pollutant transport. There were many experimental evaluation of spray drift in USA. However, in Korea, spray drift was known as one of scientific terms and had no meaning in applicator training.

Spray drift was affected by specification of operational parameters (pressure, working speed, boom height, nozzle arrangement) as well as micro-meteorological parameters such as wind velocity in horizontal and vertical directions and atmospheric stability near ground.

There were considerable amount of researches on micro-meteorology over a rough surface such as urban wind and wind in forest, wind in corn field etc.

Raupach and Thom(1981) reported an wind velocity model in planted regions as Eq.(1). This equation were reported to be valid in many plantation(Rhee, 1991; Baldocchi, 1987)

$$u(z) \;=\; \left(\begin{array}{ll} \dfrac{u_*}{\varkappa}\,\mathrm{Ln}(\dfrac{z-d_0}{z_0}) & \text{for } z > H_c \\ \dfrac{u_*}{\varkappa}\,\mathrm{Ln}(\dfrac{H_c-d_0}{z_0})\,e^{\gamma(\frac{z}{H_c}-1)} & \text{for } z \leq H_c \end{array} \right) \text{ ---------- } (1)$$

Here, $\varkappa$ represented for von Karman, which is normally taken as 0.4 in field condition. u_* was the friction velocity at certain height where stress was constant.

Wilson et. al.(1982) and Amiro (1987) measured air velocity in a corn field, and forest respectively. They set sampling rate at 100 Hz because turbulence eddy size in atmosphere was large.

Rhee(1991) suggested a statistical model for evaluation spray drift using a Random Walk Model that required very specific information on wind characteristics to generate a realistic random number generator that could describe atmospheric turbulence near ground.

Spray drift evaluation in paddy field based on experimental and theoretical approaches has been undergoing. In this paper dealt micro-meteorology in paddy field was reported.

MATERIALS AND METHODS

Experimental location and time

The experiments was accomplished at a paddy field in the University Farm of Seoul National University. The location was selected as far as possible (about 70 m away) from surrounding buildings. In most cases wind was blowing from West to East in the rice growing season.

Measurement of air velocities were conducted from early August to Late September. During the first half, measurement was conducted at every 5 days and during the other half, at every 10 days. Time of measurement were selected as 10AM, 1PM, and 5PM to measure velocities at various stability conditions. At every measurement, height of rice canopy, ambient air temperatures at 2.5m and 10m above the ground, and air velocities at every 10cm from 10cm to 200 cm above the ground with probe allocating unit.

Measurement system

Air velocity in paddy field was measured by an hot wire anemometer system (IFA-300, Constant Temperature Anemometer, TSI) with a 2-dimensional film probe(Model 1243 Boundary Layer Cross Flow "X" Probe). Overview of the measurement system was shown in Fig. 1 and the general specifications were summarized in Table 1.

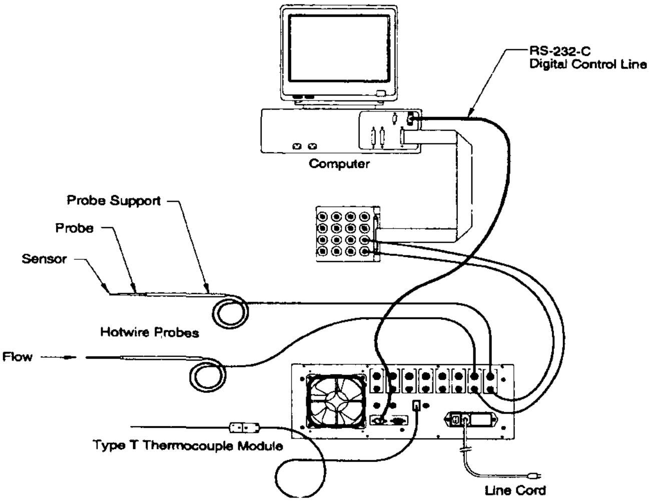


Fig. 1 Overview of thermal anemometer system.

The anemometer probe was set on a motor driven positioning system, which led the probe at every 10cm from 10cm to 160 cm above the ground. In order to measure velocity profile, sampling time was limited by the number of probes. In this study, sampling rate was 200 Hz which was higher than the generally used rate. Sampling time of 40.96 sec and measurement at 16 locations required 20 min for one set of measurement.

Table 1 Specification of IFA-300

Amplifier drift	$0.3\mu V/℃$
Operating resistance	2 to 80ohms
No. of channels	Up to 8 per cabinet
Frequency response	300kHz(without tuning)
Output	Bridge voltage to 11.5V
Temp. measurement	Type-T thermocouple

Table 2 Specification of hot wire probe (Model 1243)

Sensor designation	Boundary layer
Fluid	Gas
Sensor type	Tungsten film
Sensor orientation	45°
Sensor position	Upstream

Calibration and probe

Response of anemometer probes were known to change by environments. The probe was calibrated using a self developed calibrator. In the field experiments temperatures were not constant. Calibration of the probe from 0 to 10 m/s of velocity range at 20, 25, 30℃ was performed. Voltage output signals from the probe were modeled as 4th order polynomials which was calibrated at 30℃ condition. Minor temperature difference was modified by the anemometer system.

Atmospheric stability

Atmospheric stability near surface was measured by the standard equation in ASAE standard as Eq.(2). Ambient air temperature at 2.5m and 10m above the ground and mean air velocity at 5m height were measured. SR values greater than zero could be interpreted as the atmosphere are stable and smaller than zero would be unstable.

$$SR = \frac{10^5(t_{10} - t_{2.5})}{U_5^2} \quad \text{-----------------------------} \quad (2)$$

SR = *Stability Ratio*, ℃s^2/m^2

here, $t_{10} - t_{2.5}$ = *Temperature difference between* 10*m* and 2.5*m elevation*, ℃

U_5 = *Horizontal wind velocity at* 5*m elevation*, *m/s*

RESULT AND DISCUSSIONS

General information

Date of experiments and general information related to the measurement such as time of measurement, atmospheric stability ratio, and plant canopy(rice) were summarized in Table 3.

Table 3 General information related to the measurements

Date	Time	SR value	Canopy height(cm)	Wind direction
12 Aug.	11:20 ~ 12:20	-5144.08	60	NNW
16 Aug.	12:15 ~ 13:10	424152.15	70	E
22 Aug.	11:05 ~ 12:30	-873474.74	80	WSW
	15:25 ~ 16:40	71431.67	80	W
30 Aug.	15:07 ~ 16:40	-39632.39	95	ESE
7 Sept.	15:05 ~ 15:58	723208.41	94.67	EN
20 Sept.	16:45 ~ 17:35	-348143	95.95	W
30 Sept.	10:20 ~ 11:25	-554188	95	WNW

Autocorrelation with height

Autocorrelation could supply some information whether the sampling time was long enough. The times when autocorrelation intersected the time axis were analyzed and showed in Fig. 2. In the figure, measurement height was 0.11Hc(10cm), 0.74Hc(70cm), 1.47Hc(140cm), here Hc represented for the canopy height.

As shown in graph, time of zero autocorrelation in the vertical direction became nearly constant after 20 sec., and those in the horizontal direction were changing, which could be interpreted that the sampling time for the horizontal velocity was not long enough. However, sampling time could not be expanded because elongation of the sampling time would lead environmental changes during measurement.

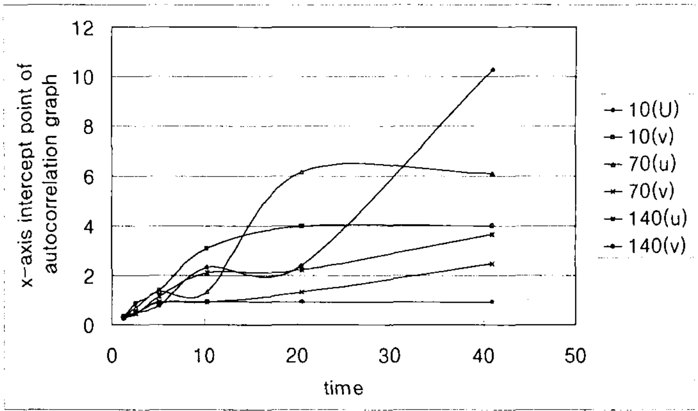


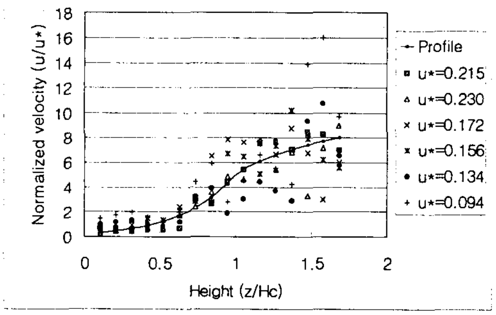
Fig. 2 X-axis intercept point of autocorrelation graph.

Mean wind profile

In this study, the model of wind profile was adopted as that of Raupach and Thom, (1981) as Eq. (3).

$$u(z) = \begin{cases} \dfrac{u_*}{0.4}\,\mathrm{Ln}\left(\dfrac{z-0.7H_c}{0.04H_c}\right) & \text{for } z>H_c \\ \dfrac{u_*}{0.4}\,\mathrm{Ln}\left(\dfrac{H_c-0.7H_c}{0.04H_c}\right)e^{2.95\left(\frac{z}{H_c}-1\right)} & \text{for } z\leq H_c \end{cases} \text{-----} \quad (3)$$

Fig. 4 showed the normalized shear stress at various height. Frictional velocity in the model was determined using velocities at 140 cm. In this study turbulence was assumed to be 2-dimensional. The assumption might lead underestimation of the friction velocity.



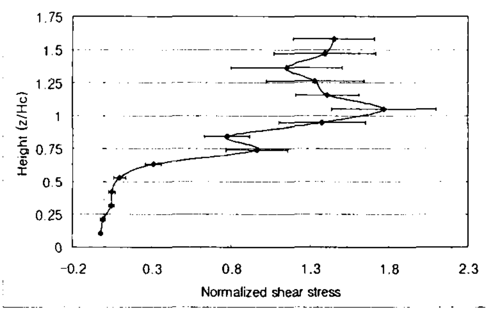


Fig. 3 Mean velocity profile (Hc=95cm).

Fig. 4 Normalized shear stress (Hc=95cm).

Zero plane displacement d_0 was interpreted as the height where stress reduced to half by Thom(1975). According to him, the zero plane displacement was in range of 0.70Hc and 0.72Hc. The best curve fitting of air velocities when

Hc = 80cm was obtained when $z_0=0.04H_c$, $d_0=0.72H_c$, $r=2.4$ and when Hc = 95cm, $z_0=0.04H_c$, $d_0=0.7H_c$, $r=2.95$. Raupach and Thom(1981) recommended $z_0=0.066H_c$, $d_0=0.75H_c$, $\gamma=3$ for most crops and Rhee(1991) reported $z_0=0.066H_c$, $d_0=0.73H_c$, $\gamma=1.3$ were best set of parameters for soybean.

The measured data in paddy showed smaller values in both zero-plane displacement and roughness length(z_0), that could be attributed to the fact that rice was more flexible than other crops.

Turbulence intensity(TI)

Turbulence intensities before ear emergence (23 Aug.) were showed in Fig. 5. Turbulence intensities above the canopy height were smaller than those below the canopy height and nearly constant around 0.4.

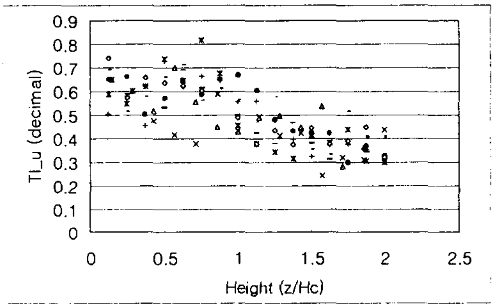


Fig. 6 Turbulence intensities of horizontal velocities before ear emergence.

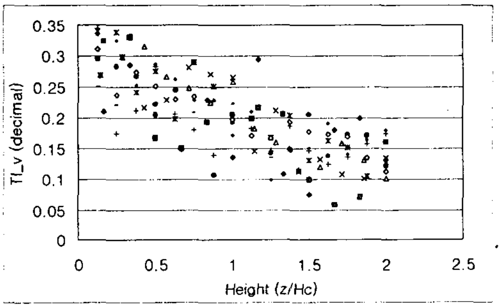


Fig. 5 Turbulence intensities of vertical velocities before ear emergence.

TI of vertical velocities were generally smaller than those of horizontal velocities. Legg and Raupach(1992) and Walklate(1987) assumed TI at below 0.3Hc to be constant in their researches. In our data, TI of vertical velocities were showed decreasing tendency with canopy height and reached nearly constant value when the measurement height were larger than 1.5Hc.

The above result on TI was consistent with result of Shaw et al, (1974a) and Finnigan(1979a). Higher value of the horizontal TI than the vertical TI could be attributed to the effect of the ground.

Skewness and kurtosis

Skewnesses of horizontal component velocities were measured to be positive.

This meant that the probability functions of horizontal velocities were skewed and asymmetric. Skewness was smaller near ground, increased as height increased up to 0.5~0.7Hc, and decreased until height reached around 1.0~1.5Hc. Skewness was constant above 1.5 Hc and 1.0 Hc before and after rice ear emergence.

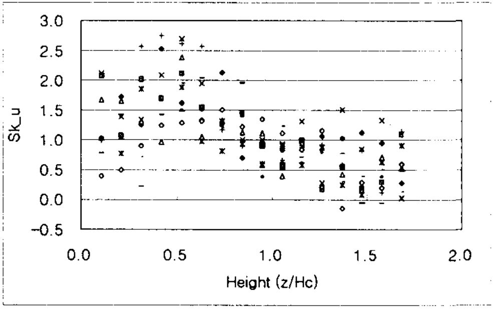


Fig. 7 Skewness of horizontal velocities after ear emergence.

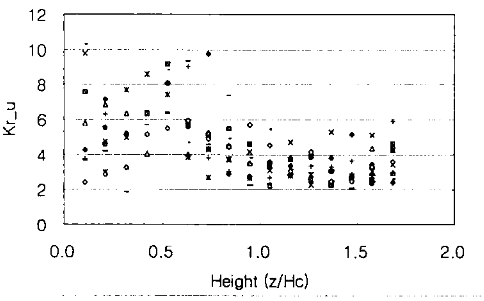


Fig. 8 Kurtosis of horizontal velocities after ear emergence.

Kurtosis of horizontal component of velocities was shown in Fig. 8. Kurtosis increased up to 0.7~0.8Hc and decreased with height and reached to about 3 and 4 for horizontal and vertical component respectively(Kurtosis of the normal distribution is 3). In other words, Air velocities above the plant canopy were interpreted as they had a probability function close to that of the normal distribution. Height of maximum kurtosis were found at 0.7Hc and 0.5Hc for before and after rice ear emergence. The large value of kurtosis could be interpreted as the existence of large eddies that could penetrate into canopy. Skewness and kurtosis showed similar pattern.

Reynolds stress

Reynolds stress defined as $\overline{u'v'}/\sigma_u\sigma_v$ showed negative coefficient of correlation. This meant that turbulence above and within canopy was not homogeneous. Negative Reynolds stress was found in the boundary layer. In paddy field, Reynolds stresses were in the range of -0.45~-0.6 and its maximum reached to -0.6. In most cases, Reynolds stresses at various heights

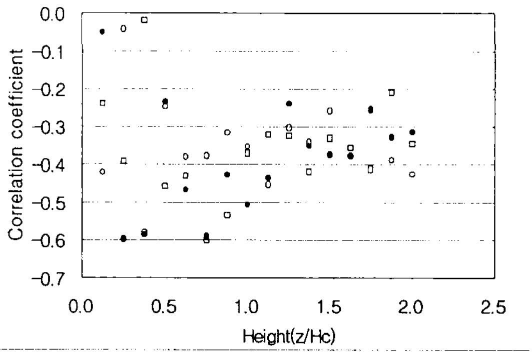


Fig. 9 Reynolds stress with height

were too much dispersed to be modeled, however value of Reynolds stress decreased as height increased. Fig. 9 showed Reynolds stresses at 22 AUG.(Hc= 80cm) in unstable atmospheric condition.

CONCLUSIONS

Micrometeorology in paddy field was measured in paddy field using a hot wire anemometer system and a 2-dimensional film probe at various heights from 10 to 160 cm above the ground. Main results were summarized as follows.

1. Mean wind profile was modeled as;

$$u(z) = \left\{ \begin{array}{ll} \dfrac{u_*}{0.4} \mathrm{Ln}\left(\dfrac{z-0.7H_c}{0.04H_c}\right) & \text{for } z > H_c \\ \dfrac{u_*}{0.4} \mathrm{Ln}\left(\dfrac{H_c-0.7H_c}{0.04H_c}\right) e^{2.95\left(\frac{z}{H_c}-1\right)} & \text{for } z \leq H_c \end{array} \right\}$$

2. Turbulence intensities were greater as close to the ground and became constant at heights greater than 1.5Hc, where TIs were 0.4 and 0.15 in horizontal and vertical direction respectively.

3. Skewness and kurtosis showed similar pattern in paddy as measurement height increased. They were decreased and reached constant values after certain height.

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