

Characterisation of Momentum, Energy and Water Vapour Fluxes in a Potato (*Solanum tuberosum* L.) Field

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ABSTRACT

In a potato field under tarai conditions of Uttar Pradesh, the momentum (T), sensible heat (H) and water vapour (E) fluxes were found to be relatively higher in well irrigated plot compared to rainfed. The values of T, H and E were almost zero except few variations during morning and evening hours on the days of observations during the crop growing season due to calm wind, low vapour pressure and temperature gradients. The highest values of T, H and E were obtained only during 1100, 1200 and 1300 hrs of the days. The peak values of T, H and E obtained under rainfed and well irrigated treatments during the season were found to be 28 and 32 g m⁻² s⁻¹; 1.7 and 2.0 k cal cm⁻² s⁻¹ and 0.036 and 0.055 g m⁻² s⁻¹, respectively for Kufri Bahar potato cultivar.

Introduction

In the plant ecosystem physiological processes are regulated by the change in aerodynamic characteristics of various fluxes. Legg *et al* (1981) reported that for the crop ratios of zero plane displacement (d) and roughness parameter (Z₀) to crop height varied little throughout the crop season. Virmani (1991) reported that momentum flux (T), sensible heat flux (H) and water vapour flux (E) were higher in irrigated as compared to rainfed moong crop. The objective of the present investigation was to characterise momentum, sensible heat and water vapour fluxes associated with crop growth parameters in a potato field.

Materials and Methods

A field experiment was conducted at Crop Research Centre of G.B.Pant University of Agriculture and Technology, Pantnagar, Distt. Udham Singh Nagar, during the winter season of 1992 - 93 with Potato (*Solanum tuberosum* L.) crop cultivar Kufri Bahar. Pantnagar is situated in the tarai belt at the foothills of Shivalic range of Himalayas at 29°N latitude, 79°30' E longitude and at an altitude of 243.84 m above the mean sea level. The soil of the experimental site was classified as Patherchatta sandy loam (Deshpande *et al.*, 1971) which falls under Order - Mollisol, family - coarse loamy, mixed, hyperthermic and series Patherchatta sandy loam. The potato crop variety Kufri Bahar was planted on 30 -10 -1992 and all agronomic and plant protection measures were followed as per the agronomic recommendations. The required micrometeorological variables viz. air temperature and vapour pressure using Assmann

Psychrometer and wind speed using small cup anemometers, were monitored at desired heights above the potato crop canopy in a 50 m x 50 m plots grown under rainfed (T₀) and well irrigated (T₂) conditions on 39, 50, 61, 78 and 91 days after planting (DAP).

The aerodynamic characteristics of potato viz. roughness parameter (Z₀), zero plane displacement (d) and their ratios with crop height Z₀/h and (d/h) and friction velocity (u*) were calculated using Szeicz *et al.* (1969) and Stanhill (1969), empirical relationships :

$$\log_{10} Z_0 = 0.997 \log_{10} h - 0.883 \quad \dots(1)$$

$$\log_{10} d = 0.979 \log_{10} h - 0.154 \quad \dots(2)$$

$$u(Z) = \frac{u^*}{k} \ln \frac{Z - d}{Z_0} \quad \dots(3)$$

Where h is plant height, Z₀ is roughness parameter, d zero plane displacement, u(Z) mean wind speed (m/s) at height Z from the soil surface, k is Von Karman's constant. From these values the momentum (T), sensible heat (H) and water vapour (E) fluxes were calculated following analogous equations given by Rosenberg *et al.* (1983) :

$$\text{Momentum flux, } T = e_a K_m \frac{du}{dz} \quad \dots(4)$$

$$\text{Sensible flux, } H = e_a C_p K_h \frac{dq}{dz} \quad \dots(5)$$

Table 1. Variations in roughness parameter (Z_0), Zero plane displacement (d), Z_0/h and d/h ratios during the crop season under rainfed (T_0) and well irrigated (T_2) conditions during the crop season

Date	Days after planting	Treatments	Crop height (m)	Z_0 (m)	d (cm)	Z_0/h	d/h
09.12.92	39	T_0	0.099	0.015	0.073	0.151	0.737
		T_2	0.140	0.021	0.102	0.150	0.729
19.12.92	50	T_0	0.125	0.019	0.092	0.152	0.736
		T_2	0.221	0.032	0.160	0.144	0.724
30.12.92	61	T_0	0.131	0.020	0.096	0.152	0.733
		T_2	0.228	0.034	0.165	0.149	0.724
16.01.93	78	T_0	0.136	0.021	0.099	0.154	0.728
		T_2	0.234	0.035	0.169	0.149	0.722
30.01.93	91	T_0	0.136	0.021	0.099	0.154	0.728
		T_2	0.234	0.035	0.169	0.149	0.722

$$\text{Water vapour flux, } E = \frac{(M_w/M_a)}{P} e_a K_w \frac{de_a}{dz} \quad \dots(6)$$

where, K_m , K_h and K_w are the turbulent exchange coefficients for momentum, sensible heat and water vapour, respectively; e_a is the air density; c_p is the specific heat at constant pressure; P is the atmospheric pressure; du/dz , dq/dz and de_a/dz are the vertical gradients of mean wind speed, potential temperature and vapour pressure, respectively; M_w and M_a are the molecular weights of water vapour and air. Following the Reynold's analogy, these exchange coefficients were assumed identical. The respective values of K_m were determined using the relationship given by Sutton (1953):

$$k_m = k u^* Z \quad \dots(7)$$

Results and Discussion

Roughness parameter (Z_0), zero plane displacement (d) and friction velocity (u^*): The results of the roughness parameter (Z_0), zero plane displacement (d) and their ratios with plant heights are given in Table 1. It appears from these results that Z_0 and d increased with crop height. Z_0 increased from 0.015 to 0.021 under T_0 and 0.021 to 0.035 in T_2 treatments. However, the ratios Z_0/h and d/h varied from 0.152 to 0.730 during the crop season. The friction velocity showed a diurnal increasing trend whenever wind speed (u) increased and decreased when u decreased during the day time of observations. On 39 th Day after planting (DAP), u^* was zero at 0700 and 0800 hrs in both T_0 and T_2 treatments reaching to values of

19×10^{-2} and 21×10^{-2} m/s, respectively, in these respective treatments at 1200 hrs and thereafter decreased reaching to a zero value at 1700 hrs of observation. At 50 DAP, u^* in T_0 and T_2 at 1400 hrs was zero when u became zero. The highest values of u^* were found to be 38×10^{-2} and 42×10^{-2} m/s in T_0 and T_2 treatments, respectively showing that u^* was always higher in T_2 compared with T_0 treatment during the potato crop season (Table 2).

Momentum flux (T), Sensible heat flux (H) and Water vapour flux (E): In general T , H and E were higher in T_2 compared to T_0 (Table 3). At 39 DAP T was zero at 0700 hrs increasing to a peak value of 8 and $10 \text{ g m}^{-2} \text{ s}^{-1}$ at 1400 hrs in T_0 and T_2 treatments, respectively and reached to zero during 1700 hrs of the day. At 61, 78 and 91 DAP also a similar trend of variation in momentum flux was noticed. The maximum value of sensible flux on 39 DAP were found to be 6×10^{-1} and $4 \times 10^{-1} \text{ k cal cm}^{-2} \text{ s}^{-1}$ in T_0 and T_2 treatments, respectively. The peak values of H were found to be 17×10^{-10} and $14 \times 10^{-1} \text{ k cal cm}^{-2} \text{ s}^{-1}$ on 91 DAP at 1300 hrs of the day. The water vapour fluxes (E) were also found to vary during the crop season. At 39 DAP E was zero and the value ranged from 0.5 to 29×10^{-3} and 0.3 to $19 \times 10^{-3} \text{ g m}^{-2} \text{ s}^{-1}$ during 1000 to 1500 hrs of the day in T_0 and T_2 treatments, respectively. The highest value of E was found to be 55×10^{-3} in T_2 and $31 \times 10^{-3} \text{ g m}^{-2} \text{ s}^{-1}$ in T_0 treatments during the potato crop season.

These results clearly indicate that, momentum,

Table 2. Day time variations in friction velocity (u^*) above the potato crop at 30 cm above crop canopy in rainfed (T_0) and irrigated (T_2) treatments during the crop season

DAP	Z(m)	Treat- ment	Friction velocity ($\times 0.01 \text{ ms}^{-1}$)										
			0700 hrs	0800 hrs	0900 hrs	1000 hrs	1100 hrs	1200 hrs	1300 hrs	1400 hrs	1500 hrs	1600 hrs	1700 hrs
39	0.40	T_0	0	0	0	2	7	19	10	19	7	0	0
	0.44	T_2	0	0	0	3	8	21	8	21	11	0	0
50	0.43	T_0	0	0	0	3	5	8	8	0	16	8	0
	0.52	T_2	0	0	0	3	6	10	16	0	25	6	0
61	0.43	T_0	0	0	3	8	13	21	16	11	8	0	0
	0.53	T_2	0	0	2	6	16	24	16	13	10	0	0
78	0.44	T_0	0	0	16	16	16	16	30	3	11	0	0
	0.53	T_2	0	0	16	19	16	19	29	3	16	0	0
91	0.44	T_0	0	0	0	10	6	8	38	11	3	0	0
	0.53	T_2	0	0	0	10	6	6	42	10	3	0	0

Table 3. Day time variations in momentum flux (T) sensible heat flux (H) and water vapour flux (E) above the potato crop in rainfed (T_0) and irrigated (T_2) treatments in Potato during the crop season

DAP	Treat- ment	Time (hrs)										
		0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700
Momentum flux ($\text{g m}^{-2} \text{ s}^{-1}$)												
39	T_0	0	0	0	0.4	2	4	2	8	5	0	0
	T_2	0	0	0	0.7	3	5	4	10	5	0	0
50	T_0	0	0	0	0.7	2	4	5	0	23	2	0
	T_2	0	0	0	0.8	3	6	4	0	31	3	0
61	T_0	0	0	0.7	2	9	14	11	5	4	0	0
	T_2	0	0	0.8	3	14	21	18	7	6	0	0
78	T_0	0	0	11	11	19	19	28	0.7	3	0	0
	T_2	0	0	18	16	27	24	32	0.8	9	0	0
91	T_0	0	0	0	1	0	9	18	5	4	0	0
	T_2	0	0	0	3	2	10	36	8	2	0	0
Sensible heat flux ($\times 0.1 \text{ Kcal cm}^{-2} \text{ s}^{-1}$)												
39	T_0	0	0	0	0.1	0.4	6	4	1	0.4	0	0
	T_2	0	0	0	1	0.4	1	1	4	2	0	0
50	T_0	0	0	0	0.3	2	2	2	0	9	0.9	0
	T_2	0	0	0	0.4	8	4	3	0	20	4	0
61	T_0	0	0	0.3	0	2	4	0.9	6	0.4	0	0
	T_2	0	0	0	0.4	3	8	2	2	0.7	0	0
78	T_0	0	0	0.9	8	0.9	4	3	3	6	0	0
	T_2	0	0	1	12	1	6	4	0	1	0	0
91	T_0	0	0	0	1	3	1	17	0	0.8	0	0
	T_2	0	0	0	0.7	1	2	14	7	1	0	0

Table 3 contd.

DAP	Treat- ment	Time (hrs)										
		0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700
Water vapour flux (X 0.001 g m ⁻² s ⁻¹)												
39	T ₀	0	0	0	0.5	29	26	16	5	18	0	0
	T ₂	0	0	0	0.3	16	12	2	6	19	0	0
50	T ₀	0	0	0	4	11	4	36	0	31	7	0
	T ₂	0	0	0	2	5	10	4	0	3	3	0
61	T ₀	0	0	2	14	16	31	4	5	1	0	0
	T ₂	0	0	10	0	2	30	9	25	7	0	0
78	T ₀	0	0	6	8	11	9	14	3	4	0	0
	T ₂	0	0	2	55	13	7	27	2	0	0	0
91	T ₀	0	0	0	0	0	0.3	3	5	0.4	0	0
	T ₂	0	0	0	2	2	3	0.1	5	3	0	0

sensible heat and water vapour fluxes behaved in such a way that at most time of observations, except few variations, their values in rainfed treatment were quite low compared to their respective values in well watered plot.

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