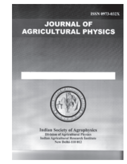
Vol. 16, No. 1&2, pp. 62-70 (2016)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in



Research Article

Radiation Interception and its Extinction, Humidity and Growth Attributes within Maize Canopy under Different Growing Environments

NAVNEET-KAUR AND PRABHJYOT-KAUR*

School of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana-141004, Punjab

ABSTRACT

Field experiments were conducted during *kharif* 2014 and 2015 at the research farm of the Punjab Agricultural University, Ludhiana to evaluate variations of micrometeorological parameters namely photosynthetic active radiation (PAR) and relative humidity, within maize canopy under different growing environments. Treatments comprised of four sowing dates (4th week of May, 2nd week of June, 4th week of June and 2nd week of July) and two maize cultivars (PMH 1 and PMH 2) in a randomized block design. Incoming PAR (%) was higher at the top and reduced towards the middle and bottom of the canopy. Sowing dates had a great influence on interception of PAR, which was highest for crop sown in 4th week of May. Among cultivars, PMH 1 showed higher interception of PAR under all the sowing dates. This could be due to better canopy architecture in PMH 1 (more plant height and LAI) compared to PMH 2. The interception of the PAR was the maximum at 60 days after sowing in all cases, and reduced thereafter due to leaf senescence. The extinction coefficient decreased with crop age *i.e.*, with onset of leaf senescence, and this leads to more light penetration within the canopy. The relative humidity (RH) remained higher at the bottom compared to the top of the crop canopy under all the treatments and reduced with crop age within the crop canopy.

Key words: Sowing date, Photosynthetic active radiation, Relative humidity, Extinction coefficient, Maize

Introduction

A significant amount of heat and water vapor enters the atmosphere as a result of exchange between the active surface and the lowest layers of atmosphere. As a result, a change of air temperature and humidity inside and above the canopy occurs. This way, every plant community creates its own microclimate (Kredl *et al.,* 2012).

The photosynthetically active radiation (PAR), between 400 and 700 nm wavelength, represents most of the visible solar radiation. Photosynthesis is dependent not only on intensity but also on the distribution of intercepted radiation within the canopy. Generally, light interception varies with crop development from emergence to the harvesting (Liu *et al.*, 2012). Dry matter (DM) production is always positively related to light interception. The light interception decreases exponentially from top to bottom of canopy. Typically, foliage photosynthetic capacity increases from bottom to top of the canopy (Niinemets, 2007). When solar radiation reaches the top of maize canopy, more than 50% of PAR is absorbed by the canopy, part of the radiation is reflected back, and the other part is transmitted to the bottom of the canopy.

*Corresponding author,
Email: pksidhu@pau.edu

Canopy extinction coefficient (*k*) is another important factor which indicates the amount of light penetration rate inside canopy. The crop may experience moisture or temperature stress and may undergo within-canopy microenvironment change that may or may not be helpful for the crop (Adak *et al.*, 2012).

Understanding within-canopy microclimatic variations can assist in better understanding of plant microclimate characteristics and its effect on plant processes (Jaya *et al.*, 2001). Within plant canopy, microclimatic factors can affect the surrounding microenvironment of leaves, thus, affecting the net photosynthetic rate (P_N). Effect of RH in the photosynthetic process of leaf at canopy in the micro-level can alter stomata conductance, affecting plant transpiration and P_N (Sciutti and Morini, 1995). The effect of RH in the photosynthetic process can affect surface evaporation and uptake of soil moisture, thus, affecting the nutrients of crop needed for growth (Swan and Volum, 1986). Moreover, the temperature and humidity are key variables on which epidemiologic processes such as infection, latency, lesions growth and sporulation of pathogens are depended upon (Henze *et al.,* 2007). The changes in sowing time alters the crop microclimate by affecting penetration of radiation due to changes in leaf area index, and thus influences soil temperature within canopy temperature, RH and soil moisture in a way of energy exchange processes.

The present study was done with the objective to assess vertical profiles of micrometeorological variables at the top, midway and near-ground at different growth periods of two maize cultivars under variable sowing periods.

Material and Methods

Study area

The field experiment was conducted at research farm of the School of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana in the *kharif* season of 2014 and 2015. It is located at 30°542 N latitude and 75°82 E longitude with an altitude of 247 metres above mean sea level in the central plain region of Punjab.

Study design

Two maize cultivars (PMH 1 and PMH 2) were sown in four dates (4th week of May, 2nd week of June, 4th week of June and 2nd week of July) in a randomized block design. The maize crop was sown with a seed rate of 20 kg ha^{1} by dibbling two seeds hill^{-1}. The fertilizers were applied @ 157, 60, 30 and 25 kg ha^{-1} for PMH 1 and @109, 30, 20 and 25 kg ha^{-1} for PMH 2, respectively through urea, SSP (Single super phosphate), MOP (Muriate of potash) and zinc sulphate. Entire quantity of P, K and zinc sulphate and 1/3 of N was applied at planting and remaining N was applied in two equal splits *i.e.*, at knee high and at pre-tasselling stages of the maize crop.

Leaf area index

The LAI was recorded at 15 days interval with the help of a Plant Canopy Analyzer (LiCOR-make). The LAI was measured by placing the sensor once above the canopy, and at four different points below the canopy diagonally across the rows. Height of 5 plants in each plot was randomly recorded and averaged at 15 days interval. The height was measured from the ground surface to the base of the upper fully developed leaf.

Photosynthetically active radiation (PAR) interception

PAR measurements were taken at top, middle and bottom of the crop. The PAR was measured between 10:00 and 16:00 h within the crop canopy at 15 days interval starting from the 45 days after sowing (DAS). The data were used for calculating PAR interception by the crop as under:

$$\text{PAR interception (\%)} = \frac{\text{PAR(I)} - \{\text{PAR(T)} + \text{PAR(R)}\}}{\text{PAR(I)}} \times 100$$

Where,

PAR (I) = PAR above canopy (W m^{-2})

PAR (T) = PAR transmitted to the ground (W m^{-2})

PAR (R) = PAR reflected from the canopy (W m^{-2})

Extinction coefficient (k)

Light extinction co-efficient ('k') value was worked out by using the following formula:

$$I = I_o \exp^{(-k*LAI)}$$

LAI : Leaf area index

I : Light flux density below the canopy

I_o : Light flux density above the canopy

E : The base to the natural logarithms

k : Extinction co-efficient

Relative humidity (%)

Psychron (Belfort make, model 566 series) was used to record the dry and wet bulb temperature above, middle and below the crop canopy at 15 days interval starting from the 45 DAS and the RH was derived from dry and wet bulb temperature by using Psychrometric tables. Diurnal cycles of dry and wet bulb temperature were taken with hourly interval from 10:00 and 16:00 h.

Results and discussion

Growth attributes

Data on periodic growth attributes of maize on 45, 60, 75 DAS and at physiological maturity under different sowing dates and cultivars during the crop years 2014 and 2015 are presented in Table 1 to 4. Plant height decreased with delay in sowing from May to July. The crop sown during 4^{th} week of May attained higher plant height compared to other sowing dates. The crop sown during 2^{nd} week of July recorded lower plant height than other sowing dates. Among the cultivars, PMH 1 had greater plant height. Similar results of decreasing plant height with delay in sowing are given by Law and Emison (2009).

The LAI was higher during the second year of study. At 45 DAS, the LAI was higher under the early date of sowing, whereas the 4^{th} date of sowing recorded lower values. The PMH 1 cultivar had higher LAI at 45 DAS during both the years of study. The LAI was maximum at 60 DAS after which it started decreasing, indicating leaf senescence. At 60 DAS, the first date of sowing had significantly higher LAI compared to other sowing dates. The LAI reduced with delay in sowing and was significantly lower under the 4^{th} sowing date. The cultivar PMH 1 had significantly higher LAI (5.5 during both the years) than PMH 2 at 60 DAS. As the crop started maturing, the LAI started decreasing at 75 DAS up to physiological maturity. At physiological maturity, the LAI was higher in 1^{st} date of sowing and reduced with delay in sowing. Cv. PMH 1 had significantly lower LAI at physiological maturity during both the years of study.

Incoming PAR

The incoming PAR was higher at the top of canopy and reduced downward. The incoming PAR was minimum at the bottom of the canopy under all sowing dates and cultivars during both the years. The amount of transmitted PAR towards the middle and bottom of the canopy was minimum at 60 DAS and increased thereafter due to the reduction in LAI with the maturity of the crop. Better capturing of solar radiation during vegetative stage was due to increased LAI under different sowing dates.

The albedo (%) in the crop canopy increased towards the bottom the canopy. The albedo was less during early stages and became higher at later growth periods. The lesser radiation was reflected during early periods of growth due to the high vegetative growth, and it increased as the crop started maturing.

Photosynthetically active radiation (PAR) interception

The interception (%) of the PAR at different days after sowing increased from 45 DAS, became maximum at 60 DAS and then decreased at 75 DAS till physiological maturity. The middle part of the maize canopy had higher intercepted PAR compared to the bottom of the canopy. In PMH 1, maximum 82.7 and 84.0% PAR was intercepted at the middle and 10.6 and 8.4% at the bottom of

Table 1. Albedo (%), PAR interception (%) and extinction coefficient (k) of maize cultivars for crop sown during 4th week of May in *kharif* 2014 and 2015

Days after sowing	Plant height (cm)	Incoming PAR (W m^{-2})			PAR Albedo (%)			PAR interception (%)		LAI	Extinction coefficient (k)	
		Top	Middle	Bottom	Top	Middle	Bottom	Middle	Bottom		Middle	Bottom
					PMH 1 (2014)							
45	177.5	1475.4	220.0	97.5	4.4	7.5	8.5	80.7	11.6	4.3	0.44	0.63
60	280.7	1460.5	193.1	86.8	4.1	6.0	8.5	82.7	10.6	5.2	0.39	0.54
75	290.9	1265.9	268.8	188.5	4.9	8.2	9.6	73.8	9.5	4.4	0.35	0.43
Physiological maturity	290.9	1096.0	470.3	386.5	6.6	8.7	9.7	50.5	10.5	2.4	0.35	0.43
					PMH 1 (2015)							
45	179.6	1333.0	182.6	73.6	3.7	6.9	8.5	82.6	11.0	4.4	0.45	0.66
60	283.9	1260.5	155.7	84.2	3.6	5.5	6.6	84.0	8.6	5.5	0.38	0.49
75	294.7	1211.9	204.9	121.9	4.3	5.2	6.8	78.8	10.3	4.7	0.38	0.49
Physiological maturity	294.7	1133.4	442.5	341.3	4.7	7.9	8.7	56.3	10.5	2.6	0.36	0.46
					PMH 2 (2014)							
45	169.9	1475.4	259.1	136.3	4.8	7.1	8.7	77.6	11.9	3.7	0.47	0.64
60	248.8	1460.5	241.0	141.1	4.6	6.6	7.2	78.9	10.4	4.3	0.42	0.54
75	250.4	1265.9	317.9	245.9	5.5	9.6	10.0	69.4	8.8	3.5	0.39	0.47
Physiological maturity	250.4	1096.0	519.7	437.6	6.9	9.8	10.1	45.7	9.8	2.1	0.36	0.44
					PMH 2 (2015)							
45	175.4	1333.0	199.9	110.1	4.3	7.4	8.8	80.7	9.9	4.0	0.47	0.62
60	254.2	1260.5	172.5	123.0	4.0	6.5	5.8	82.4	7.0	4.5	0.44	0.52
75	256.7	1211.9	266.7	196.9	4.7	9.2	9.4	73.2	8.5	3.6	0.42	0.50
Physiological maturity	256.7	1133.4	501.8	411.3	6.5	9.3	9.6	49.2	10.4	2.2	0.37	0.46

Table 2. Albedo (%), PAR interception (%) and extinction coefficient of maize cultivars for crop sown during 2nd week of June in *kharif* 2014 and 2015

Days after sowing	Plant height (cm)	Incoming PAR ($W m^{-2}$)			PAR Albedo (%)			PAR interception (%)		LAI	Extinction coefficient (k)	
		Top	Middle	Bottom	Top	Middle	Bottom	Middle	Bottom		Middle	Bottom
					PMH 1 (2014)							
45	173.2	1439.3	242.3	123.5	4.9	6.8	7.8	78.2	12.0	3.9	0.46	0.63
60	267.1	1277.8	194.6	113.1	5.0	6.1	7.2	79.8	10.5	4.4	0.43	0.55
75	280.5	1135.2	288.6	187.6	5.5	7.8	7.7	69.0	12.5	4.1	0.33	0.44
Physiological maturity	280.5	1118.2	537.2	429.6	6.4	7.9	8.3	45.6	12.2	2.2	0.33	0.43
					PMH 1 (2015)							
45	178.2	1410.4	211.2	105.7	2.5	6.9	6.6	82.2	9.2	4.1	0.46	0.63
60	272.8	1171.4	166.3	100.6	3.0	5.8	6.9	82.4	8.0	4.7	0.42	0.52
75	284.3	1125.8	277.2	174.4	3.8	6.7	6.8	71.3	11.3	4.4	0.32	0.42
Physiological maturity	284.3	1085.8	518.4	408.1	4.6	5.9	7.0	47.1	12.0	2.4	0.31	0.41
					PMH 2 (2014)							
45	153.8	1439.3	295.5	162.3	5.2	7.0	8.5	74.3	13.0	3.5	0.45	0.62
60	237.9	1277.8	218.5	136.6	4.9	8.4	8.4	78.0	9.9	4.1	0.43	0.55
75	238.9	1135.2	316.6	222.5	6.0	9.3	9.7	66.1	11.7	3.0	0.43	0.54
Physiological maturity	238.9	1118.1	603.7	505.8	6.5	9.5	9.7	39.5	10.1	1.5	0.41	0.53
					PMH 2 (2015)							
45	160.3	1410.4	250.9	150.6	2.6	7.7	8.9	79.2	8.6	3.8	0.45	0.59
60	240.5	1171.4	194.3	123.8	3.3	8.6	6.1	79.8	8.1	4.2	0.43	0.54
75	241.9	1125.8	314.6	239.3	5.1	8.2	7.5	66.5	9.8	3.1	0.41	0.50
Physiological maturity	241.9	1085.8	564.7	469.5	4.8	7.0	7.9	42.5	10.1	1.7	0.38	0.49

Table 3. Albedo (%), PAR interception (%) and extinction coefficient of maize cultivars for crop sown during 4th week of June in *kharif* 2014 and 2015

Days after sowing	Plant height (cm)	Incoming PAR ($W\ m^{-2}$)			PAR Albedo (%)			PAR interception (%)		LAI	Extinction coefficient (k)	
		Top	Middle	Bottom	Top	Middle	Bottom	Middle	Bottom		Middle	Bottom
					PMH 1 (2014)							
45	165.8	1222.2	277.5	146.5	5.3	5.6	6.6	72.0	14.8	3.6	0.41	0.59
60	259.3	1209.9	241.6	119.7	5.0	5.3	7.1	75.0	14.1	4	0.40	0.58
75	277.0	1118.1	339.8	195.3	6.1	7.5	7.9	63.5	16.8	3.4	0.35	0.51
Physiological maturity	277.0	1091.1	622.5	493.8	6.2	7.7	8.1	36.7	13.6	1.6	0.35	0.50
					PMH 1 (2015)							
45	173.2	1212.1	217.4	142.2	3.9	7.6	8.2	78.1	8.8	3.9	0.44	0.55
60	261.4	1185.5	185.9	111.6	4.0	7.1	8.1	80.3	9.1	4.3	0.43	0.55
75	280.8	1118.2	315.0	190.6	5.4	6.9	8.3	66.4	14.6	3.6	0.35	0.49
Physiological maturity	280.8	1115.8	609.6	459.5	5.6	6.9	8.5	39.1	15.5	1.8	0.34	0.49
					PMH 2 (2014)							
45	148.6	1222.2	297.5	167.3	6.0	6.2	7.5	69.7	15.1	3.3	0.43	0.60
60	228.9	1209.9	270.0	129.7	5.4	5.9	7.7	72.3	15.7	3.8	0.39	0.59
75	229.3	1118.1	435.9	291.9	6.0	6.6	8.4	55.0	16.3	2.4	0.39	0.56
Physiological maturity	229.3	1091.1	676.0	546.4	6.5	7.7	8.4	31.5	13.6	1.3	0.37	0.53
PMH 2 (2015)												
45	154.0	1212.1	242.3	167.6	4.8	7.8	8.5	75.2	9.4	3.4	0.47	0.58
60	232.1	1185.5	192.4	132.7	4.2	7.5	7.6	79.6	8.0	3.9	0.47	0.56
75	232.6	1118.2	370.9	268.7	5.8	5.5	6.2	61.0	13.1	2.6	0.42	0.55
Physiological maturity	232.6	1115.8	644.6	532.4	5.7	6.7	7.5	35.7	12.2	1.4	0.39	0.53

Table 4. Albedo (%), PAR interception (%) and extinction coefficient of maize cultivars for crop sown during 2nd week of July in *kharif* 2014 and 2015

Days after sowing	Plant height (cm)	Incoming PAR ($W m^{-2}$)			PAR Albedo (%)			PAR interception (%)		LAI	Extinction coefficient (k)	
		Top	Middle	Bottom	Top	Middle	Bottom	Middle	Bottom		Middle	Bottom
					PMH 1 (2014)							
45	143.0	1210.9	441.6	296.2	6.3	6.7	7.1	57.2	15.9	2.6	0.39	0.54
60	250.6	1112.6	342.8	243.4	5.3	6.1	7.0	63.9	12.3	3.4	0.35	0.45
75	253.2	1104.5	496.5	367.0	5.4	6.3	7.1	49.7	14.3	2.7	0.30	0.41
Physiological maturity	253.2	1034.8	705.1	555.3	6.5	6.8	7.5	25.3	16.4	1.5	0.26	0.41
					PMH 1 (2015)							
45	146.5	1188.1	377.1	276.0	4.4	7.6	8.1	63.3	10.8	2.7	0.43	0.54
60	252.6	1128.6	276.6	257.0	4.4	6.6	6.3	70.5	4.8	3.6	0.39	0.41
75	261.9	1110.4	419.1	320.0	4.7	6.7	7.0	56.9	11.3	3.0	0.32	0.41
Physiological maturity	261.9	1064.9	678.8	557.7	5.8	7.2	8.1	29.9	12.6	1.6	0.28	0.40
					PMH 2 (2014)							
45	139.4	1210.9	519.2	374.3	6.4	6.7	7.7	50.7	15.5	2	0.42	0.59
60	222.2	1112.6	351.4	250.8	5.2	6.7	7.4	63.3	12.1	3.1	0.37	0.48
75	223.2	1104.5	620.4	493.6	5.9	7.1	7.7	38.0	13.4	1.7	0.34	0.47
Physiological maturity	223.2	1034.8	740.4	627.0	6.7	7.4	7.9	21.7	12.4	1.1	0.30	0.46
					PMH 2 (2015)							
45	144.6	1188.1	404.1	321.6	4.8	8.2	8.9	60.6	9.1	2.4	0.45	0.54
60	224.5	1128.6	286.7	237.7	4.6	6.2	6.0	69.4	7.8	3.4	0.40	0.46
75	224.8	1110.4	541.7	476.8	5.1	6.9	6.9	45.4	7.8	1.8	0.40	0.47
Physiological maturity	224.8	1064.9	700.2	620.7	5.9	7.1	7.5	27.7	8.7	1.2	0.35	0.45

the canopy during 2014 and 2015, respectively for the May-sown crop. For PMH 2, maximum 78.9 and 82.4% was intercepted at middle and 10.4 and 7.0% at the bottom of the canopy during 2014 and 2015, respectively for the May-sown crop. The intercepted PAR in the maize canopy reduced with delay in sowing which could be due to reduced LAI. The July-sown crop intercepted the lowest PAR compared to the other sowing dates. For the July-sown crop, PMH 1 intercepted maximum 69.4 and 72.7 % at the middle and 14.1 and 9.8% at the bottom during 2014 and 2015, respectively (Table 4). The cv. PMH 2 sown during the July intercepted 67.1 and 68.0 % in the middle and 12.9 and 9.6 % in bottom of the canopy, respectively. Similar results of reduced interception towards the lower part of the maize canopy were also reported by Liu and Song (2012). The intercepted PAR was usually higher in cv. PMH 1 at different growth periods in both the years.

Extinction coefficient

The variety PMH 1 had lesser value of the extinction coefficient (k) as compared to PMH 2 as intercepted radiation was higher in case of PMH 1, which led to decreasing extinction coefficient. The coefficient increased with delay in sowing during both the years. The crop sown during 4th week of May had lower value of ‘k’ as compared to other sowing dates whereas crop sown during 2nd week of July had high values. The reduction in ‘k’ with advancement of the crop growth in wheat crop was also reported by Lungaria and Shekh (2006).

Relative humidity

The relative humidity profile of the crop indicated that the RH was lower at top of the canopy and increased towards the middle and bottom of the canopy at different time intervals during both the seasons (data not shown). The diurnal variations in the RH indicated that it was higher during morning and evening hours and reduced at noon. The RH in both the cultivars was higher at 45 and 60 DAS due to higher vegetative growth, and it decreased as the crop moved towards maturity and the leaf senescence led to reduction in the canopy structure of the crop. Adak *et al.* (2012) also reported a decrease in the relative humidity with increasing height in mustard crop.

Conclusions

The present study highlights the influence of sowing period and cultivars on micrometeorological parameters within maize canopy. The PAR interception was higher in PMH 1 cultivar, and when it was sown during May. The delayed sown crop had lower interception of PAR due to decreased LAI.

Acknowledgement

The financial assistance provided by the UGC, New Delhi in the form of Maulana Azad National Fellowship for post graduate studies is duly acknowledged.

References

Adak, T., Kumar, G., Narjary, B. and Chakravarty, N.V.K. 2012. Micrometeorological dynamics within mustard (*Brassica juncea*) crop canopy under semi-arid conditions of northern India. *J. Agrometeorol.* **14**(1):45-49.

Henze, M., Beyer, M., Klink, H. and Verreet, J.A. 2007. Characterizing meteorological scenarios favourble for septoria tritici infections in wheat and estimation of latent periods. *Plant Disease* **91**(11):1441-1445.

Jaya, K.D., Bell, C.J. and Sale, P.W. 2001. Modification of within-canopy microclimate in Maize for intercropping in the lowland tropics. *Proc. Australian Agron. Conf.*, Australian Society of Agronomy.

Kredl, Z., Streda, T., Pokorny, R., Kmoch, M. and Brotan, J. 2012. Microclimate in the vertical profile of wheat, rape and maize canopies. *Acta Universitatis Agriculturae Et Silviculturae Mendelianae Brunensis* LX, No. 1, 79-90.

Law, K.E. and Emison, S.U.R. 2009. Growth and yield of maize as influenced by sowing date and poultry manure application. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* **37**(1): 199-203.

Liu, T.D. and Song, F.B. 2012. Maize photosynthesis and microclimate within the canopies at grain-filling stage in response to narrow-wide row planting patterns. *Photosynthetica* **50**(2): 215-22.

Liu, T., Song, F., Liu, S. and Zhu, X. 2012. Light interception and radiation use efficiency response to narrow-wide row planting patterns in maize. *Australian J. Crop Sci.* **6**(3): 506-513.

Lungaria, M.M. and Sheikh, A.M. 2006. Radiation interception, light extinction coefficient and leaf area index of wheat (*Triticum aestivum* L.) crop as influenced by row orientation and row spacing. *J. Agric. Sci.* **2**(2): 43-54.

Niinemets, U. 2007. Photosynthesis and resource distribution through plant canopies. *Plant Cell Enviro.* **30**:1052-1071.

Scuitti, R. and Morini, S. 1995. Water loss and photosynthesis of plum plantlets is influenced by relative humidity during rooting in vitro. *J. Horti. Sci.* **70**: 221-228.

Swan, I.R. and Volum, A.G. 1986. Estimation of evaporation from temperature and relative humidity. *J. Australian Instt. Agric. Sci.* **52**: 222-24.

Received: June 21, 2016; Accepted: October 27, 2016