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Short communication

Evaluation of growth and yield of wheat cultivars using agroclimatic indices under poplar based agroforestry system in Punjab

K. K. GILL, NAVNEET KAUR[1] and R.I.S. GILL[1]

School of Climate Change & Agricultural Meteorology
[1]Deptt. of Forestry & Natural Resources
Punjab Agricultural University, Ludhiana -141004
**Email : kgill2002@gmail.com*

Agroforestry has emerged as one of the viable alternatives for diversification from dominant rice-wheat system in north western India. Farmers of Punjab have achieved high economic returns by adoption of poplar based agroforestry system. Cultivation of crops in between the tree rows gives additional income every year while trees continue growing for 6-8 years. In poplar, leaf fall starts in October and by the month end about 13% leaves fall which gradually increase to 27 and 84% by the end of November and December, respectively. The trees become totally leaf less in January and February. New flush of leaves starts appearing by end March and the trees are fully flush by end April (Gill *et al.*, 2009). Poplar being winter deciduous tree, almost all the *rabi* crops like wheat, mustard, potato, oats, berseem, etc. can be raised throughout its rotation.

Wheat is one of the most economical crop that can be successfully grown with poplar right from their planting till harvest. There is a gradual yield reduction (10–46%) of wheat grown under poplar with the increase in age of trees (first–sixth year). Such yield loss is often compensated by the sale of poplar wood at the end of rotation (Gill *et al*.,2007).Whea trequires relatively cool temperature of below 25^{o}C and fair supply of soil moisture during the growing season. Under Punjab conditions, its growing season (October – April) coincides with a period of very low to high evaporative demand, abundant sunshine and moderate to high solar radiation conditions. Trees modify the microclimate by reducing photosynthetically active radiation (PAR), air temperature and by increasing the relative humidity (RH) in their understorey. Agroclimatic models based on thermal indices can play an important role in predicting growth and yield of crops. Attempts have been made by different workers to predict phenology, growth and yield of sole wheat and other crops (Ghosh *et al*, 2000; Hundal *et al,* 2003). However, it is a new attempt to work out these indices for different wheat cultivars under different set of environments i.e. open as well as under poplar block plantation.

The field experiments were conducted during *rabi* 2012-13 to evaluate growth and yield of three wheat cultivars (V_1-PBW 343, V_2-PBW 550 and V_3-HD 2967) sown on two dates(D_1 – 23rdOctober, D_2 – 20thNovember) under 4 year old poplar plantation as well as open conditionsat the research farm of Deptt. of Forestry and Natural Resources,Punjab Agricultural University, Ludhiana (30^0 54¢ N, 75^0 48¢ E, 247 m above mean sea level). Poplars were planted at a spacing of 5 m x 4 m which is a widely adopted spacing by farmers. The area between the tree rows (5 m wide strip) was used to sow wheat varieties. The experiments were laid out in Randomized Block Design. The wheat cultivars were raised following the recommended package of practices of the Punjab Agricultural University, Ludhiana. The crop under trees as well as under open condition was managed in the same. The crop received 100 kg Nha^{-1}(urea) and 30 kg P_2O_5ha^{-1}(single super phosphate). At sowing, one half of nitrogen and all P_2O_5were applied as basal dose. The remaining half dose of nitrogen was applied with first irrigation.

The growing degree days (GDD) was determined as per Nuttonson (1955) by assuming base temperature of 5 ^{o}C.Growing degree days (GDD) were accumulated from the date of sowing to each date of sampling to give accumulated GDD.Photothermal units (PTU) i.e. the product of GDD and corresponding daylength for that day were computed on daily basis. Photothermal units (PTU) were accumulated from the date of sowing to each date of sampling to give accumulated PTU.Heat use efficiency (HUE) for seed and straw yield was computed to compare the relative performance of different wheat cultivars and treatments with respect to utilization of heat using the formula :

Heat use efficiency (HUE)=Total Yield (kg ha^{-1}) /

Table 1: Mean of phenological calendar of wheat cultivars for different dates of sowing under different environments during *rabi* 2012-13

Phenological stage	Wheat cultivars						Date of sowing			
	PBW 343		PBW 550		HD 2967		D_1(23 Oct.)		D_2(20 Nov.)	
	Open	Under Poplar	Open	Under Poplar	Open	Under Poplar	Open	Under Poplar	Open	Under Poplar
Start emergence	5	5	5	5	5	5	5	5	5	5
CRI stage	24	20	22	21	21	20	21	19	23	20
Jointing	71	63	67	59	55	59	70	67	59	60
Flag leaf	87	77	87	75	70	71	80	75	82	74
Booting	96	91	95	87	80	83	90	89	90	87
Anthesis	118	113	111	109	101	106	112	120	107	109
Milking	127	122	121	118	111	118	122	127	116	119
Soft dough	138	131	124	127	120	127	133	137	121	128
Physiological maturity	148	142	139	139	129	140	148	149	129	140

Table 2: Photosynthetically active radiation (PAR) interception at periodic intervals under different environments

DAS	D1 (23 October)							D2 (20 November)					
	Open			Under Poplar				Open			Under Poplar		
	PBW	PBW	HD	PBW	PBW	HD	DAS	PBW	PBW	HD	PBW	PBW	HD
	343	550	2967	343	550	2967		343	550	2967	343	550	2967
60	75.3	79.3	90.5	66.9	68.9	80.1	30	61.4	66.2	85.6	66.4	70.9	81.6
100	53.2	78.6	89.7	50.9	55.3	68.4	70	60.8	70.3	84.3	55.1	60.7	66.0
140	65.3	75.4	86.1	55.4	63.6	76.7	110	62.4	74.3	87.7	52.4	67.5	78.5

Accumulated GDD (^oC day)

The photosynthetically active radiation (PAR) observations were taken at different intervals during the crop season. The data was taken at the top, middle and bottom of the crop canopy and PAR interception was worked out for different treatments.

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

PAR (I) = PAR incident at the top of the canopy

PAR (R) = PAR reflected by the crop canopy

PAR (T) = PAR transmitted to the ground

Agroclimatic indices :

The phenological calendar for different cultivars for wheat cultivars under poplar as well as open conditions from sowing to physiological maturity are given in Table 1. The cultivar PBW took more days to physiological maturity (148) whereas lowest number of days (129) weare taken by cultivar HD 2967in open conditions. Similar, phenological calendar has been given for wheat cultivars under different dates of owing (Table 1). In early sown wheat cultivars more number of agroclimatic indices was required for the crop to attain maturity. However, in general as sowing delayed then comparatively lesser number of agroclimatic indices were utilized by wheat crop to attain physiological maturity and resulted in yield loss. But different trend has been observed in wheat crop when grown under poplar. Under poplar, November sown crop gave better yield as compared to October sown crop although heat units acquired by the crop were less in November in comparison to October. In early sown wheat crop i.e. (October sown) heavy leaf fall of poplar restricts the emergence, reduces plant stand and hinders the crop growth. However, in November sown crop, emergence is better due to more availability of light owing to 13-20% leaf fall of poplar in the month of October (Gill *et al,* 2009) as compared to the earlier sown crop. These factors might have contributed towards better yield during November under poplar plantation as compared to October.

Table3: Heat use efficiency (HUE) of wheat cultivars for two dates of sowing under open and shade conditions during crop season (*Rabi* 2012-13)

	Dates of sowing	Cultivars	AGDD (°C day)	APTU(°C day hr)	Straw yield (kgha^{-1})	Grain yield (kgha^{-1})	Straw yield HUE (kgha^{-1}°C day^{-1})	Grain yield HUE (kgha^{-1}°C day^{-1})
Open	D_1	V_1	1800	19426	10675	3755	5.9	2.1
		V_2	1678	18394	10225	5100	6.1	3.0
		V_3	1320	13810	11350	5450	8.6	4.1
	D_2	V_1	1391	15505	8850	3268	6.4	2.3
		V_2	1276	13201	10225	4775	8.0	3.7
		V_3	1380	14202	11425	5775	8.3	4.2
Under	D_1	V_1	1218	13372	9468	2750	7.8	2.3
Poplar		V_2	1175	12855	7900	3443	6.7	2.9
		V_3	1114	12114	9625	3770	8.6	3.4
	D_2	V_1	949	10515	7683	2375	8.1	2.5
		V_2	935	10059	9808	3880	10.5	4.1
		V_3	1019	11385	10400	3970	10.2	3.9
	Mean		1271	13737	9803	4026	7.9	3.2
	SD		268.15	2871.07	1193.45	1054.62	1.48	0.80
	CV		4.7	4.8	8.2	3.8	5.4	4.0

Furthermore, differential PAR interception by wheat crop under poplar and open environment resulted in reduction of wheat yield in understorey as compared to open. Amongst the cultivars, HD 2967 recorded higher PAR interception than other cultivars under both the environments and different date of sowing.The cv. HD 2967 attained 88.8% PAR followed by cv. PBW 550 (77.8%) and least by cv. PBW 343 (64.3%) during first date of sowing in open conditions. Whereas, under poplar the corresponding values for these cv's were 75.1%, 62.6% and 57.7%, respectively. Similar trend has been observed during second date of sowing under both the environments. The PAR interception was 30 % higher in HD 2967 than PBW 343 under poplar block plantation when sown during 20thNovember. The wheat cultivars received 12% less PAR under poplar than open condition irrespective of time of sowing(Table 2).

However, amongst cultivars, PBW 343 performed better as compared to PBW 550 and HD 2967 in terms of utilization of agroclimatic indices both under poplar as well as in open. The accumulated growing degree-days acquired by cv.PBW 343 are 1218 and 949, for cv. PBW 550 are1175 and 935 and for cv. HD 2967 are1114 and 1019 under poplar while in open conditions these cultivars acquired 1800 and 1391, 1678 and 1276 and 1320 and 1380, respectively for October and November sown wheat crop. Wheat cultivar, PBW 550 utilized less heat units to attain physiological maturity as compared to both HD2967 and PBW 343 cultivars.

Mean, standard deviation (SD) and coefficient of variation (CV) for AGDD for wheat under different environments were calculated over a different time of sowings. The results revealed that wheat crop needed 1474 heat units for attaining physiological maturity with a SD of $\pm$213 heat units and CV of 6.9 % in open conditions while 1065 heat units with a SD of $\pm$124 heat units and CV of 8.6 % under poplar plantation. Hence, under Punjab conditions GDD can be used as an agro-meteorological index for evaluating yield of wheat under poplar.

Grain yield and heat use efficiency (HUE)

Accumulated GDD, total dry matter accumulated at the time of physiological maturity and grain yield of wheat for different treatments are given in Table 3. HUE was computed to determine the number of growing degree days required to produce unit amount of dry matter / grain yield per growing degree days (Table 3). In general, it was observed that grain and straw yield were more in October sown crop in open conditions and November sown crop under poplar

plantation. The highest grain yield of three cultivars was recorded as 5775 and 3970 kgha^{-1} for cv HD-2967 and lowest 3268 and 2375 kgha^{-1}is for PBW 343 both under open and shade conditions. Similarly, highest straw yield of 11425 and 10400 kgha^{-1} for cv HD-2967 was recorded during 2012-13. It has been observed that HD 2967 performed better during November sown conditions both under poplar and open conditions.

Heat-use efficiency (HUE) was computed to determine the grain or straw yield produced per unit of growing degree-days for wheat cultivars. The grain and straw yield HUE was more in wheat crop sown in November as compared to October. This may be attributed to the fact that in November sown crop less number of heat units were utilized to attain physiological maturity while higher grain and straw yields were recorded. While under open conditions, higher HUE for grain and straw yield has been observed under October sown crop as more heat units were accumulated in early sown crop. Generally, with delay in sowing, the accumulation of heat units decreases. Similar results have been reported by Khichar and Niwas (2007) from Hisar in Haryana.

The highest grain yield HUE of 4.2 kgha^{-1}^{o}C day^{-1} was recorded in open conditions and 3.9 kgha^{-1}^{o}C day^{-1}under poplar for cv. HD 2967 in November sown crop. Similarly, highest straw yield HUE of 8.3and 10.2 kgha^{-1}^{o}C day^{-1}for cv HD-2967 was recorded under open and shade conditions during 2012-13 (Jat *et al*., 2003). The mean HUE for wheat was 3.2 and 7.9 kgha^{-1}^{o}C day^{-1}for grain and straw yield, respectively. The CV for grain and straw yield HUE was nearly 4.0% and 5.4 % amongst different treatments of wheat crop, respectively.

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