

## Photosynthesis in Relation to Light Interception under Different Fertility Level in Pearl Millet under Rainfed Environment

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**Abstract** A field experiment was conducted during *kharif* season with randomized block design allocating 13 fertilizers levels with three replications on pearl millet and observations were taken of light interception and photosynthesis pearl millet crop under rainfed conditions. The photosynthetically active radiation, photosynthesis, leaf conductance and transpiration were measured in all the treatments. Solar radiation trapped by chlorophyll in the process of photosynthesis provides the substances for growth and yielded more in T<sub>13</sub> (60 kg N + 30 kg P<sub>2</sub>O<sub>5</sub> + 20 kg K<sub>2</sub>O/ha) as compared to other treatments. In control treatments as stomatal conductance was minimum 181 m mol m<sup>-1</sup>s<sup>-1</sup> in T<sub>1</sub> (control). The per cent absorbed photosynthetically active radiation (PAR) was higher

at 45 days after sowing in all the treatments and reverse trend was observed in case of transmitted PAR and maximum in treatment T<sub>13</sub> (284 m mol m<sup>-2</sup>s<sup>-1</sup>). Similar trends were observed in transpiration rate, water use efficiency deferred in fertility levels, but it was not significant except at 30 days after sowing.

**Keywords** Light interception, Photosynthesis, Nitrogen level, Pearl millet, Fertility level.

### Introduction

Pearl millet is one of the four most important including millets grown in the tropics, hot and dry climate and also can grown in areas like arid or semi arid where rainfall is not sufficient, drought tolerant warm season. Pearl millet is a photosensitive and thermo sensitive long day plant [1]. The globally it is grown on 27 million hectare in some of the harsh, arid and dry-semi-arid tropical environments of South Asia and sub-Sahara Africa [2]. It is important dual-purpose cereal crop in India, which not only provides grains for human consumption but also fodders and grain for cattle. Pearl millet is a major food, feed and fodder crop for feeding the world population. The growing conditions of pearl millet vary from near optimum with high external inputs to highly drought prone environments. This allows for prioritization of research incognizance of production constraints and different requirement of various crop-growing regions. Pearl millet crop is grown during the *kharif* season in arid

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**Table 1.** Effect of fertility levels on growth, growing period and yield of pearl millet.

Treatments	Leaf area	Dry matter	Growing period	Yield (kg ha <sup>-1</sup> )
T <sub>1</sub>	1.69	1262.2	64.7	1256.5
T <sub>2</sub>	1.71	1333.5	66.7	1355.3
T <sub>3</sub>	1.76	1382.3	67.7	1404.7
T <sub>4</sub>	1.75	1307.2	67.7	1558.3
T <sub>5</sub>	1.79	1342.6	68.7	1832.6
T <sub>6</sub>	1.82	1326.7	68.7	1333.3
T <sub>7</sub>	1.84	1368.8	69.7	1448.6
T <sub>8</sub>	1.83	1350.4	69.7	1591.2
T <sub>9</sub>	1.96	1379.2	69.7	1911.9
T <sub>10</sub>	1.99	1380.1	70.7	1410.1
T <sub>11</sub>	2.10	1378.6	70.7	1536.4
T <sub>12</sub>	2.12	1393.9	70.7	1602.2
T <sub>13</sub>	2.16	1398.1	71.7	2063.1

and semi arid region of the country and is cultivated over an area of 7.95 million hectare with production of 8.79 million tonnes of grains and an average productivity of 1106 kg ha<sup>-1</sup> [3]. Temperature is key component of climate, determining the sowing time and consequently rate and duration of growth and productivity of the crop. The crop growth and development depends upon the thermal time or quantitative effect of temperature. Agroclimatic indices are useful for assessing the impact of agrometeorological variables at different crop growth stages. Solar radiation is an important weather parameter, which asset in crop production and seldom a limiting factor in the arid and

semi arid regions. Radiation has two roles in crop production, namely the photosynthetically active radiation (PAR) for photosynthesis and thermal conditions for physiological processes. Intercepted radiation was the main factor determining both crop and spike growth and grain number solar radiation trapped by chlorophyll in the process of photosynthesis provides the substances for plant growth and crop yields. The fertilization is determining the yield and affecting plant productivity of pearl millet. Nitrogen fertilizers also improve metabolic efficiency, coupled with higher photosynthesis. Rathore et al. [4] reported that radiation absorption coefficient of photosynthetic active radiation was higher and less radiation transmission in 90 kg N + 45 kg P<sub>2</sub>O<sub>5</sub>/ha due to more leaf area index. Dry matter (DM) production is always positively related to light interception, light interception decreases exponentially from top to bottom of canopy. Typically, foliage photosynthetic capacity increases as the gradient from the bottom to the top of canopy increases [5]. Hence, study was under taken to verify rate of photosynthesis in relation to radiation interception by pearl millet under rainfed environment.

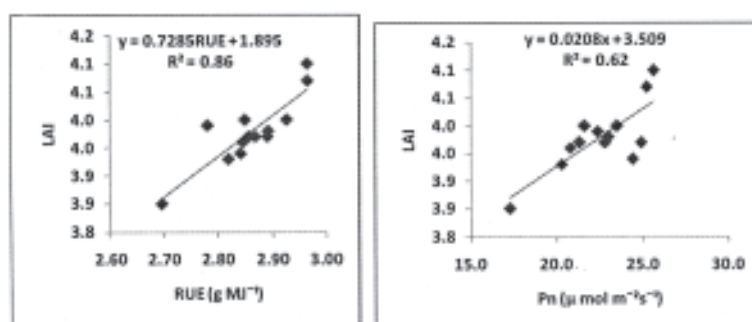
## Materials and Methods

Experimental site, location and climate condition

The field experiment was conducted at the research area of Dry Land Agriculture, Chaudhary Charan

**Table 2.** Effect of fertility levels on transmitted, reflected and absorbed photosynthetically active radiation (% of incident PAR) at different days after sowing in pearl millet. T-Tranmitted PAR, R-Reflected PAR and A-Absorbed PAR.

Treatments	30 DAS				45 DAS				60 DAS			
	T	R	A	RUE	T	R	A	RUE	T	R	A	RUE
T <sub>1</sub>	27.1	5.7	67.2	3.6	24.9	5.0	70.1	4.0	36.5	4.1	59.4	4.8
T <sub>2</sub>	25.7	6.0	68.4	3.7	22.7	3.7	73.6	3.9	35.2	4.3	60.5	4.3
T <sub>3</sub>	19.5	5.6	74.9	3.6	14.7	4.2	81.1	3.9	34.7	4.3	61.0	4.3
T <sub>4</sub>	16.6	4.7	78.7	3.6	7.0	4.2	88.8	4.0	32.7	4.5	62.7	4.4
T <sub>5</sub>	14.6	6.0	79.4	3.74	5.1	4.4	90.5	3.8	31.9	4.7	63.4	4.3
T <sub>6</sub>	19.0	6.1	75.0	3.7	11.3	4.2	84.5	3.8	30.7	3.7	65.6	4.4
T <sub>7</sub>	22.5	5.5	71.9	3.9	10.5	4.1	85.4	3.8	28.5	4.5	67.0	4.4
T <sub>8</sub>	16.4	5.7	77.9	3.9	8.6	4.3	87.1	3.80	27.4	4.7	67.9	4.4
T <sub>9</sub>	19.4	6.0	74.5	4.2	5.7	4.1	90.2	3.8	25.0	4.2	70.9	4.5
T <sub>10</sub>	19.7	6.0	74.3	4.4	18.5	4.5	77.0	3.9	23.1	4.4	72.5	4.6
T <sub>11</sub>	18.1	5.5	76.4	4.48	6.2	4.6	89.2	3.9	23.9	5.0	71.0	4.6
T <sub>12</sub>	15.5	5.9	78.6	4.53	5.9	4.1	90.0	4.0	22.1	4.2	73.8	4.7
T <sub>13</sub>	13.9	5.1	81.0	4.58	5.1	4.3	90.6	4.0	22.2	4.6	73.2	4.8



**Fig. 1.** Relationship of leaf area index (LAI) with radiation use efficiency and photosynthetic rate in pearl millet (Pooled for all treatments).

Singh Haryana Agricultural University Hissar, situated at 29° 10'N latitude, 75° 46'E longitude and altitude of 215.2 meters. The climate of Hissar is a typical semi-arid climate having hot and dry summer with desiccating winds. About 80% of the annual rainfall received during south west monsoon, few thunder-showers also were received during the months of December to February due to western disturbances and normal annual rainfall is around 450 mm with 28 rainy days from June to September.

Experimental details, design, crop and instrument

The experiment was laid out in randomized block design and with following 13 fertilizers levels and three replications. Quantum sensor was used to measure the photo synthetically active radiation (PAR) at three levels of crop canopy at ground, middle and above to crop canopy surface, Photosynthetic rate, transpiration rate and stomatal conductance were measured by infra red gas analyzer (IRGA, CIRAS-1/PP system, UK). The seed of pearl millet hybrid HHB 67 of pearl millet (*Pennisetum glaucum* (L) R. Br.) was sown at about 5 cm soil depth by hand ploughing in rows 45 cm apart and plant to plant distance of 15 (45×15 cm) cm in the *kharif* growing season.

Sl. No.	Treatments	Fertility levels
1	T <sub>1</sub>	Control
2	T <sub>2</sub>	40 kg N+20 kg P <sub>2</sub> O <sub>5</sub> /ha

3	T <sub>3</sub>	40 kg N+20 kg P <sub>2</sub> O <sub>5</sub> +10 kg K <sub>2</sub> O/ha
4	T <sub>4</sub>	40 kg N+ 20 kg P <sub>2</sub> O <sub>5</sub> +15 kg K <sub>2</sub> O/ha
5	T <sub>5</sub>	40 kg N+ 20 kg P <sub>2</sub> O <sub>5</sub> +20 kg K <sub>2</sub> O/ha
6	T <sub>6</sub>	50 kg N+ 25 kg P <sub>2</sub> O <sub>5</sub> /ha
7	T <sub>7</sub>	50 kg N+ 25 kg P <sub>2</sub> O <sub>5</sub> +10 kg K <sub>2</sub> O/ha
8	T <sub>8</sub>	50 kg N+ 25 kg P <sub>2</sub> O <sub>5</sub> +15 kg K <sub>2</sub> O/ha
9	T <sub>9</sub>	50 kg N+ 25 kg P <sub>2</sub> O <sub>5</sub> +20 kg K <sub>2</sub> O/ha
10	T <sub>10</sub>	60 kg N+ 30 kg P <sub>2</sub> O <sub>5</sub> /ha
11	T <sub>11</sub>	60 kg N+ 30 kg P <sub>2</sub> O <sub>5</sub> +10 kg K <sub>2</sub> O/ha
12	T <sub>12</sub>	60 kg N+ 30 kg P <sub>2</sub> O <sub>5</sub> +15 kg K <sub>2</sub> O/ha
13	T <sub>13</sub>	60 kg N+ 30 kg P <sub>2</sub> O <sub>5</sub> +20 kg K <sub>2</sub> O/ha

Physico-chemical, physical and chemical properties of soil

Soil was analyzed to determine the physicochemical properties of the experimental field. The soil texture is sandy loam, structure less and water holding capacity (WHC) of experimental field soil is 39.5% (volume by volume based or v/v). The exchangeable cation (EC) was 0.14 d S m<sup>-1</sup>. The soil chemical properties like pH level of soil were 8.1, available nitrogen (N) 156 kg per hectare, P<sub>2</sub>O<sub>5</sub> 12 kg per hectare and K<sub>2</sub>O 325 kg per hectare were observed.

## Results and Discussion

Crop growth and yield parameters were measured in all treatments and appropriate statistical technique was used for analysis of the results. The leaf area index (LAI) increased slowly initially up to 20 days after sowing and then faster and reached to its maxi-

**Table 3.** Effect of different treatments on photosynthetic rate ( $\mu \text{ mol m}^{-2}\text{s}^{-1}$ ), transpiration rate ( $\mu \text{ mol m}^{-2}\text{s}^{-1}$ ), stomatal conductance ( $\text{m mol m}^{-2}\text{s}^{-1}$ ) and water use efficiency ( $\mu \text{ mol Co}_2 \text{ m mol}^{-1}\text{H}_2\text{O}$ ) of pearl millet crop.  $P_a$  : Photosynthetic rate,  $T_r$  : Transpiration rate,  $S_c$ : Stomatal conductance, WUE: Water use efficiency, DAS: Days after sowing.

Treatments	30 DAS				45 DAS				60 DAS			
	$P_a$	$T_r$	$S_c$	WUE	$P_a$	$T_r$	$S_c$	WUE	$P_a$	$T_r$	$S_c$	WUE
T <sub>1</sub>	13.9	3.0	181	3.7	17.3	4.3	192	4.0	14.9	3.0	187	4.8
T <sub>2</sub>	15.5	4.2	206	3.7	20.3	5.2	211	3.9	16.2	3.7	203	4.3
T <sub>3</sub>	15.7	4.3	214	3.6	20.8	5.3	223	3.9	16.4	3.8	216	4.3
T <sub>4</sub>	15.8	4.4	223	3.6	21.3	5.3	235	4.0	16.9	3.8	228	4.4
T <sub>5</sub>	16.5	4.4	228	3.7	21.6	5.6	243	3.8	17.0	3.9	232	4.3
T <sub>6</sub>	17.3	4.6	240	3.7	22.4	5.9	265	3.8	18.4	4.1	245	4.5
T <sub>7</sub>	18.2	4.6	243	3.9	22.8	5.9	276	3.8	18.6	4.2	252	4.4
T <sub>8</sub>	18.6	4.7	251	4.0	23.0	6.0	288	3.8	18.7	4.2	258	4.4
T <sub>9</sub>	20.0	4.7	260	4.3	23.5	6.1	287	3.8	19.2	4.3	261	4.5
T <sub>10</sub>	21.3	4.8	272	4.4	24.4	6.3	295	3.9	20.4	4.4	270	4.6
T <sub>11</sub>	21.8	4.8	278	4.5	24.9	6.2	299	3.9	20.7	4.4	280	4.6
T <sub>12</sub>	22.0	4.8	280	4.5	25.2	6.2	301	4.0	21.6	4.5	282	4.7
T <sub>13</sub>	22.5	4.9	284	4.6	25.6	6.3	309	4.0	22.0	4.6	293	4.8
CD 5%	1.3	0.9	12.5	0.8	1.7	1.0	13.6	NS	1.8	0.5	0.9	NS

imum at 50 DAS in all treatments. LAI was affected significantly with adding the fertilizers. These trends are in agreement with obtained by Shahin et al. [6]. Grain yield was recorded minimum in control treatment is  $125.5 \text{ kg ha}^{-1}$  and maximum in T<sub>13</sub>  $2063.1 \text{ kg ha}^{-1}$ . Dry matter production of the crop was closely related to the amount of photosynthetically active radiation (PAR) intercepted and utilized by the crop canopy during the period of its active growth. Rate of photosynthesis increased from 30 to 45 days after sowing and declined thereafter till crop maturity. Crop growth (leaf area and dry matter), development and yield of pearl millet crop affected by different fertility levels are presented in Table 1. The efficient crop tends to spend their early growth to expand their leaf area and better use of solar radiation. Agronomic practices, such as fertilization, proper densities and better spatial arrangement of plants are used to accelerate ground cover and increase light interception.

#### Radiation interception

Maximum absorbed PAR was higher at 45 days after sowing in all the treatments and reverse trend was observed in case of transmitted PAR, which might be due to maximum leaf area index (Table 2). Dry matter production in pearl millet is closely related to the amount of photosynthetically active radiation inter-

cepted and utilized by the crop canopy during the period of its active growth and part of the intercepted PAR is lost through reflection and some of it portion absorbed by the crop canopy that is useful in producing the dry matter. After 45 days of sowing also, the minimum value of absorption was in control and maximum value was in treatment T<sub>13</sub>. This was due to highest leaf area index was reached in T<sub>13</sub> and minimum in T<sub>1</sub>. Fertilizer deficiency affects crop growth by reducing the pearl millet leaf area and intercepted photosynthetically active radiation. The maximum growing days (71.7) were in the T<sub>13</sub> and lowest in control (64.7) treatment from emergence to physiological maturity. The efficiency of interception of PAR depends on the leaf of the plant population as well as on the leaf shape and inclination to the canopy. Oluwasemire and Odugbenro [7] reported that higher solar radiation intercepted increased radiation use efficiency, dry matter production as well as yield among the different varieties of *Arachis*.

#### Photosynthesis

The impact of different fertility levels on photosynthetic rate in leaves of pearl millet crop was measured at 30, 45 and 60 DAS. Photosynthesis increased from 30 to 45 DAS and declined at 60 DAS. It was noticed that application of increasing fertility levels signifi-

cantly increased photosynthetic rate and was maximum in  $T_{13}$  at 45 days after sowing. Irrespective of treatments, the photosynthetic rate decreased progressively after 45 days due to mobilization of leaf nitrogen for the development of protein rich seeds. N application significantly increased the leaf photosynthesis. Higher dose of nitrogen increased the photosynthetic rate of plant leaves due to direct effect of fertilizer application on leaf area index and radiation interception. This might be due to maximum leaf area index recorded in  $T_{13}$  at this stage. Low intensity of light causes stomata closure, which restrict the entry of carbon dioxide gas, resulted in decrease of photosynthetic rate. Similar results were reported in the study of the effect of fertilizer application on photosynthesis of *Jatropha curcas* L. by Yong et al. [8].

#### Transpiration rate and stomatal conductance

Fertilizer levels also influenced transpiration rate significantly at all the growth stages (Table 3). Transpiration rate was highest 45 DAS with ranged between 3.0 to 6.3  $\text{m mol m}^{-3}\text{s}^{-1}$  in pearl millet crop.  $T_{13}$  significantly transpire more water as compared to  $T_1$  and  $T_2$  treatments. This was due to more transpiring leaf area in the treatment over  $T_1$  and  $T_2$ . Similar trend was observed in stomatal conductance where application of fertilizer levels increased the stomatal conductance during crop season. In highly fertilized treatment, stomatal conductance was 309  $\text{m mol m}^{-2}\text{s}^{-1}$  at 45 days after sowing in  $T_3$  pearl millet crop. As the doses of N,  $\text{P}_2\text{O}_5$  and  $\text{K}_2\text{O}$  increased the value of stomatal conductance also increased. Similar trend was observed on 45 days after sowing and 60 days after sowing.

The WUE increased in all the treatments from 30 to 60 days after sowing and no significant effect of fertilizer levels was observed on water use efficiency of pearl millet except at 30 DAS. This might be due to less variation in transpiration rate as compared to photosynthesis rate.

Photosynthesis rate and radiation use efficiency were directly related with leaf area index and yield (Fig. 1) photosynthesis explained up to 62 and 86% variability in leaf area index and grain yield respectively. The corresponding values of coefficient of determination were 0.86 and 0.56 in respect of leaf area index and grain yield respectively.

Based on the above result it is concluded that radiation absorption was maximum in pearl millet. Crop fertilized with 60 kg N, 30 kg  $\text{P}_2\text{O}_5$  and 15 kg  $\text{K}_2\text{O}$  per hectare in pearl millet with this fertility level observed a significant increase in photosynthesis rates.

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