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Physiological parameters, leaf area index, crop growth rate and relative growth rate of maize grown under different locations and different farming practices in Himachal Pradesh

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Abstract

A field experiment was conducted during *kharif* season 2016 at farmer's fields in district Hamirpur. The experiment included 8 treatment combinations was conducted in random block design with three replications. The experiment was carried out during June to September in Bhoranj, Nadaun and Taunidevi blocks with different dates of sowing *viz.* Gwardu (L_1) 30th May, Dhamrol (L_2) 31st May, Mann treti (L_3) 30th June and Jhandvi (L_4) 6th June of district Hamirpur. Location (L_3) i.e. Mann treti in Nadaun block was found to be the best location. Higher crop growth rate (42.5 g/m^2/day) and plant height (202.3 cm) were recorded in Nadaun block at Mann treti (Location L_3) with 500-800 mm rainfall. The Farmers practice (FP_2) showed significantly higher plant height (216.7 cm), leaf area index (1.91), crop growth rate (46.5 g/m^2/day) and relative growth rate (0.0069 g/g/day). Farmer's practice proved to be better than zero budget natural farming at all the three locations.

Key words: Farming practice, location, maize, physiological parameters and rainfall.

Maize is second most important crop of Hamirpur district of Himachal Pradesh after wheat which is grown in an area of 33,000 ha with production of 57,600 metric ton and productivity of 1745 kg per hectare (Prasad *et al.* 2014). Maize (*Zea mays* L.) is an important cereal crop of the world. It is ranked as the third most important cereal crops followed by rice and wheat in the world (FAO, 2010). This crop can be successfully grown in an area receiving annual rainfall of 60 cm which should be well distributed throughout its growth period (Panda, 2010). It is estimated that 65% of global food production depends upon rainfall, while the remaining 35% rely upon irrigation. Maize (*Zea mays*) is an important cereal crop of India and widely grown during *kharif* season for grain purpose in different parts of world. Globally maize occupies an area of 181.44 million hectare with production of 990.64 million tonnes and productivity 5460 kg per hectare (Anonymous, 2015). In India, maize is cultivated on an area of 9.42 million hectare with production of 24.35 million tonnes and productivity of 2583 kg per hectare. In Himachal Pradesh, the crop grown on an area of 0.29 million hectare with total production of 0.68 million tonnes and productivity of 2325 kg per hectare (Anonymous, 2015a). Moreover, being a C4 crop plant, having a large leaf area it is more efficient in converting solar energy to dry matter than most other cereals which can give high biological yield as well as grain yield relatively in a shorter period of time due to its unique photosynthetic mechanism (Hatch and Slack, 1966). It needs bright sunny days for an accelerated photosynthetic activity and rapid growth of plant but this has to be associated with an abundant supply of water. It can be successfully grown where night temperature does not go below 15^{o}C. Maize as purely rain fed crop may be risky in regions with mean annual rainfall less than 500 mm. The moisture requirement of crop is very peculiar, it is adapted to humid climate and has higher water requirements. Its water requirements vary according to its developmental stage. During germination period and subsequently up to early stage maize can develop with little moisture requirements. However crop requires heavy doses of water during its inflorescence. Crop needs 50-75 cm rainfall during its life span. Since rainfall has dominating influence on agriculture for nearly two third of the world's area, studies for its varied characteristics is undertaken in all countries in all season both in rainfed and irrigated farming conditions. In arid and semi-arid regions, it becomes a limiting factor of crop production. The relations of various exiting characteristics of rainfall has to be carefully studied and established in service of productive remunerative agriculture. Physiological growth analysis is a way to assess what events occurs during plant growth and eventually it is important in the prediction of yield of crop (Hokmalipour and Darbandi, 2011). Biomass partitioning is important for crop production and plants usually divert accumulated biomass to other plant parts to ensure and maintain a high production capacity (Srivastava and Gaiser, 2008). The data of different blocks of Hamirpur shows that during SW monsoon (June-September), 696.0-1283.2 mm, 525.5-1437.0 mm and 411.0-1305.3 mm rainfall is received in Bhoranj, Nadaun and Hamirpur blocks, respectively. The rainy days varied between 28-64, 17-54 and 26-65 days in Bhoranj, Nadaun and Hamirpur blocks, respectively (Anonymous, 2016). The mean variability in rainfall and rainy days during the SW monsoon is least among seasons. In general, response of rainfall on maize is different at different growth stages under different crop growing environments. There is paucity of information on rainfall characteristics and yield rainfall relations of maize growing environments of Hamirpur district. Therefore, an experiment was conducted to evaluate the variability of plant height, leaf area index, dry matter accumulation, crop growth rate and relative growth rate at different growth stages of maize.

Materials and Methods

A field experiment was conducted during *kharif* season 2016 at farmer's field in Hamirpur district. The experiment included eight treatment combinations and conducted in random block design with three replications. The experiment was carried out during June to September in Bhoranj, Nadaun and Taunidevi blocks with different dates of sowing *viz*. Gwardu (L_1) 30th May, Dhamrol (L_2) 31st May, Mann treti (L_3) 30th June and Jhandvi (L_4) 6th June of district Hamirpur. The seed of Maize variety Kanchan hybrid was sown 3-4 cm deep in furrows opened with the help of a hand plough at a spacing of 60 x 20 cm and seed rate 20 kg/ha. The farmers field were located between latitude, 31°68' N to 31°78' N and longitude between 75°52' E and 76°6' E at altitude varying from 491-997 m above mean sea level. Hamirpur falls under lower Himalayas sub humid zone of the state and is endowed with mild summers (March to June) and cool winters with high rainfall mainly during monsoon (June to September). The region receives an average rainfall ranging between 1220-1731 mm per annum, major portion of rainfall (about 80%) is received during June to September. Winter rains are received during December to March while, October, November, April and May are generally drier months and usually receive either low or no rainfall. Five plants were selected randomly from each plot. The height of these plants were measured in centimeters from the ground level to the top of the upper most leaf tip at 30 days interval from the date of sowing. The average of these observations were recorded as mean plant height. Dry matter accumulation was recorded by drawing a random sample of plants at different phenological stages at appeared at each 30 days interval up to 90 DAS. At each observation, fresh plants were cut from the ground level, kept in the paper bags and dried at 70°C in oven till constant weight was attained. The samples were weighed immediately each time after taking out from oven to avoid absorbance of moisture from air to ascertain constant weight. The leaf area (LAI) was determined as per Redford (1967).

$$\text{Leaf area index (LAI)} = \frac{\text{Total leaf area (cm}^2\text{)}}{\text{Ground area (cm}^2\text{)}}$$

Crop growth rate (CGR) (g/day/m^2) and relative growth rate (RGR) (g/g/day) were calculated by the formulae outlined by Watson (1962).

$$CGR = \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

$$RGR = \frac{(\log_e W_2 - \log_e W_1)}{(t_2 - t_1)}$$

Where, W_2 and W_1 are the total dry weight values at times t_2 and t_1, respectively.

Results and Discussion

Plant height was significantly influenced by farming practices at all growth stages and also significantly influenced by locations at all growth stages except 30 days after sowing. Farmers practice (FP_2) significantly increased the plant height (216.7 cm) at L_3 over zero budget natural farming (FP_1) at all locations. Interaction effect of farming practice and location was found to be significant. This might be due to better nutrition and good rainfall. Similar results were reported by Shamim Gul *et al*. (2015).

Dry matter accumulation was significantly influences by farming practices and locations at all growth stages except 30 DAS. Farmers practice significantly increased the dry matter accumulation over zero budget natural farming at all location. At 60 and 90 days after sowing higher dry matter accumulation was recorded in L_3- Mann treti (1443.2 g/m^2) followed by location L_4 (1443.2 g/m^2). Interaction effect of farming practice and location found to be significant at all growth stages except 30 DAS. However, lowest Dry matter accumulation recorded in the location L_1 (1291.0 g/m^2). Dry matter production rate was increased till harvesting. But the rate of increment at 60 to 90 DAS was faster as compared to other growth stages. This was due to rapid increase in plant height, stem girth, root number, length and as well as increase in leaf number and size. Beside this, the appearance of tassel and ear at this stage contributed greatly to the sharp increment of total dry matter. This result is in agreement with the findings of Ibeawuchi *et al.* (2008).

Crop growth rate was significantly influenced by farming practice and locations at all growth stages. Farmer practice significantly increased the crop growth rate over zero budget natural farming. Location L_3 recorded significantly higher crop growth rate (42.5 g/m^2/day) followed by L_4 (40.8 g/m^2/day). However, lowest crop growth rate recorded in L_1 (39.4 g/m^2/day). The rate of the crop growth was increased up to 90 DAS and then it was decreased sharply till harvest. The reason behind the increment of crop growth rate was due to accumulation of more dry matter by the plants. After 90 DAS it declined because after vegetative stage dry matter accumulation increases but the rate of accumulation was not as much as vegetative stage. The similar results were also found by Hokmalipour and Darbandi (2011), Aliu (2010) and Limpinuntana *et al*. (2010).

Leaf area index was significantly influenced by farming practice and locations at all growth stages Except 30 DAS. Farm practice followed at L_3 recorded significantly higher leaf area index (1.87) followed by L_4 (1.67). Relative growth rate was statistically influenced by farming practice and locations at all growth stages. Farmers practice statistically increased the relative growth rate over zero budget natural farming. At location L_3 recorded statistically higher crop growth rate (0.0082 g/g/day) followed by L_4 (0.0048 g/g/day). It was observed that the relative growth rate value was the highest at early growth stage and then it tends to decrease until harvest. The variation among the genotypes was due to the variation in dry matter accumulation by different genotypes Hokmalipour and Darbandi (2011).

Table 1. Effect of locations and farming practices on plant height (cm) at different growth stages

	Plant height				
	L_1	**L_2**	**L_3**	**L_4**	
			30 DAS		
Rainfall (mm)	153.4	391.4	202.7	249.8	
Farming practice					**Mean**
FP_1	28.0	23.0	26.7	24.3	25.5
FP_2	52.3	55.6	54.0	57.3	54.8
Mean	**40.2**	**39.3**	**40.4**	**40.8**	
	Farming practice (FP)		**Location (L)**	**FP x L**	
SEm±	0.42		0.60	0.84	
CD (P=0.05)	1.28		NS	2.56	

			60 DAS		
Rainfall (mm)	571.9	455.8	498.5	471.2	
Farming practice					**Mean**
FP_1	115.3	125.0	119.9	127.4	121.9
FP_2	146.1	145.7	145.4	141.7	144.7
Mean	**130.7**	**135.4**	**132.6**	**134.6**	
	Farming practice (FP)		**Location (L)**	**FP x L**	
SEm±	0.68		0.96	1.36	
	CD (P=0.05)		2.06 2.92 4.12		
			90 DAS		
Rainfall (mm)	1096.9	832.8	659.4	821.8	
Farming practice					**Mean**
FP_1	131.2	125.0	160.2	140.2	139.2
FP_2	160.2	174.1	193.6	174.2	175.6
Mean	**145.7**	**149.6**	**176.9**	**157.2**	
	Farming practice (FP)		**Location (L)**	**FP x L**	
SEm±	0.45	0.63	0.89		
CD (P=0.05)	1.35	3.03	2.70		
		Plant height at harvest			
Rainfall (mm)	1241.3	956.2	671.9	888.6	
Farming practice					**Mean**
FP_1	167.3	172.7	188.0	191.0	179.8
FP_2	203.7	205.7	216.7	205.3	207.3
Mean	**185.5**	**188.2**	**202.3**	**198.2**	
	Farming practice (FP)		**Location (L)**	**FP x L**	
SEm±	1.03		1.45	2.05	
CD (P=0.05)	3.11		4.40	6.23	

Table 2. Effect of locations and farming practices on dry matter accumulation (g/m^2) at different growth stages

			Dry matter at 30 DAS		
			Location		
	L_1	**L_2**	**L_3**	**L_4**	
Rainfall (mm)	153.4	391.4	202.7	249.8	
Farming practice					**Mean**
FP_1	88.0	96.0	125.0	105.5	103.6
FP_2	91.6	108.3	147.2	133.3	120.1
Mean	**89.8**	**102.6**	**136.1**	**119.4**	
	Farming practice (FP)		**Location (L)**	**FP x L**	
SEm±	2.2		3.0	4.3	
CD at 5%	6.5		9.2	NS	
			60 DAS		
Rainfall (mm)	571.9	455.8	498.5	471.2	
Farming practice					**Mean**
FP_1	637.3	859.3	1049.2	803.2	837.3
FP_2	1155.3	1155.1	1136.1	1152.8	1149.8
Mean	**896.3**	**1007.2**	**1092.7**	**978.0**	

	Farming practice (FP)		**Location**	**FP x L**	
SEm±	11.8		16.7	23.6	
CD at 5%	35.7		50.5	71.5	
		90 DAS			
Rainfall (mm)	1096.9	832.8	659.4	821.8	
Farming practice					**Mean**
FP_1	1131.6	1178.3	1157.1	1055.0	1130.5
FP_2	1228.0	1245.3	1395.3	1390.7	1314.8
Mean	**1179.8**	**1211.8**	**1276.2**	**1222.8**	
	Farming practice (FP)		**Location**	**FP x L**	
SEm±	19.4		27.5	38.9	
CD at 5%	59.0		NS	118.0	
		Dry matter at harvest			
Rainfall (mm)	1241.3	956.2	671.9	888.6	
Farming practice					**Mean**
FP_1	1109.7	1233.3	1338.0	1262.0	1235.7
FP_2	1472.3	1487.7	1548.4	1548.4	1502.4
Mean	**1291.0**	**1360.5**	**1443.2**	**1381.6**	
	Farming practice(FP)		**Location (L)**	**FP x L**	
SEm±	12.7		18.0	25.5	
CD at 5%	38.6		54.6	77.3	

Table 3. Effect of locations and farming practices on crop growth rate (g/m²/day) at different growth stages

		CGR 30 DAS			
			Location		
	L_1	L_2	L_3	L_4	
Rainfall (mm)	153.4	391.4	202.7	249.8	
Farming practice					**Mean**
FP_1	3.2	2.9	4.	3.5	3.45
FP_2	3.6	3.1	4.9	4.4	4.00
Mean	**3.4**	**2.9**	**4.5**	**3.9**	
	Farming practice (FP)		**Location (L)**	**FP x L**	
SEm±	0.07		0.10	0.14	
CD at 5%	0.22		0.31	NS	
		CGR 60 DAS			
Rainfall (mm)	571.9	455.8	498.5	471.2	
Farming practice					**Mean**
FP_1	21.2	22.2	34.9	28.6	26.8
FP_2	38.5	38.4	37.8	38.5	38.3
Mean	**29.9**	**30.3**	**36.4**	**33.6**	
	Farming practice (FP)		**Location (L)**	**FP x L**	
SEm±	0.4		0.6	0.8	
CD at 5%	1.2		1.7	2.2	

		CGR 90 DAS			
Rainfall (mm)	1096.9	832.8	659.4	821.8	
Farming practice					**Mean**
FP_1	37.9	39.3	38.6	35.2	37.7
FP_2	40.9	41.5	46.5	46.4	43.8
Mean	**39.4**	**40.4**	**42.5**	**40.8**	
	Farming practice (FP)		**Location (L)**	**FP x L**	
SEm±	0.6		2.1	1.3	
CD at 5%	1.9		NS	3.9	

Table 4. Effect of locations and farming practices on relative growth rate (g/g/day) at different growth stages

		RGR 30 DAS			
			Location		
	L_1	**L_2**	**L_3**	**L_4**	
Rainfall (mm)	153.4	391.4	202.7	249.8	
Farming practice					**Mean**
FP_1	0.063	0.060	0.068	0.070	0.068
FP_2	0.079	0.068	0.072	0.072	0.076
Mean	**0.071**	**0.064**	**0.076**	**0.074**	
	Farming practice (FP)		**Location (L)**	**FP x L**	
SEm±	0.005		0.006	0.009	
CD at 5%	NS		NS	NS	
		RGR 60 DAS			
Rainfall (mm)	571.9	455.8	498.5	471.2	
Farming practice					**Mean**
FP_1	0.011	0.006	0.009	0.008	0.012
FP_2	0.018	0.010	0.020	0.013	0.018
Mean	**0.010**	**0.011**	**0.017**	**0.013**	
	Farming practice(FP)		**Location (L)**	**FP x L**	
SEm±	0.006		0.009	0.013	
CD at 5%	NS		NS	NS	
		RGR 90 DAS			
Rainfall (mm)	1096.9	832.8	659.4	821.8	
Farming practice					**Mean**
FP_1	0.0032	0.0034	0.0082	0.0048	0.0049
FP_2	0.0033	0.0093	0.0116	0.0069	0.0078
Mean	**0.0032**	**0.0034**	**0.0082**	**0.0048**	
	Farming practice(FP)		**Location (L)**	**FP x L**	
SEm±	0.0011		0.0015	0.0021	
CD at 5%	NS		NS	NS	

Table 5. Effect of locations and farming practices on leaf area index at different growth stages

	Leaf area index at 30 DAS				
	Location				
	L_1	**L_2**	**L_3**	**L_4**	
Rainfall (mm)	153.4	391.4	202.7	249.8	
Farming practice					**Mean**
FP_1	0.32	0.22	0.34	0.26	0.29
FP_2	0.34	0.25	0.54	0.45	0.40
Mean	**0.33**	**0.24**	**0.44**	**0.36**	
	Farming practice (FP)		**Location (L)**	**FP x L**	
SEm±	0.004		0.006	0.009	
CD at 5%	0.01		0.02	0.03	
	Leaf area index at 60 DAS				
Rainfall (mm)	571.9	455.8	498.5	471.2	
Farming practice					**Mean**
FP_1	2.27	2.36	2.66	2.50	2.45
FP_2	2.60	2.58	2.58	2.63	2.60
Mean	**2.44**	**2.47**	**2.62**	**2.56**	
	Farming practice (FP)		**Location (L)**	**FP x L**	
SEm±	0.03		0.05	0.07	
CD at 5%	0.10		0.14	0.20	
	Leaf area index at 90 DAS				
Rainfall (mm)	1096.9	832.8	659.4	821.8	
Farming practice					**Mean**
FP_1	3.16	3.27	3.51	3.20	3.29
FP_2	3.50	3.47	3.88	3.57	3.60
Mean	**3.33**	**3.37**	**3.69**	**3.39**	
	Farming practice(FP)		**Location (L)**	**FP x L**	
SEm±	0.11		3.16	3.27	
CD at 5%	NS		NS	NS	
	Leaf area index at harvest				
Rainfall (mm)	1241.3	956.2	671.9	888.6	
Farming practice					**Mean**
FP_1	1.17	1.27	1.83	1.33	1.40
FP_2	1.44	1.37	1.91	2.02	1.74
Mean	**1.31**	**1.32**	**1.87**	**1.67**	
	Farming practice(FP)		**Location**	**FP x L**	
SEm±	0.04		0.06	0.09	
CD at 5%	0.13		0.19	0.27	

Conclusion

The findings of the present investigation clearly indicated for Location (L_3) i.e. Mann treti in Nadaun block was found to be the best location for maize growing environment receiving a rainfall of 500-800 mm during crop growing season. Higher crop growth rate and plant height were recorded in Nadaun block at Mann treti (Location L_3). Farmer's practice proved to be better than zero budget natural farming at all three locations.

Conflicts of interest: The authors declare that there is no conflict of interest in this research paper.

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