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Agro-climatic indices of fodder maize, *Zea mays* L in relation to nutritional status

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ABSTRACT

A field experiment was conducted during summer season of 2011 at the research farm of the Department of Agronomy, Punjab Agricultural University, Ludhiana to study the effect of farm yard manure (FYM) and nitrogen on the different agro-climatic indices of summer maize fodder. The experiment was laid out in split plot design with three levels of FYM in main plots and four levels of nitrogen in sub-plots. The different agro-climatic indices were GDD, photo-thermal units, helio-thermal units and phenol-thermal index were studied at 50 per cent tasseling, 50 per cent silking and harvest stage of maize fodder. Increasing level of either FYM or nitrogen lowered the GDD requirement over the lower level. Crop which received the highest quantity (25 tons) of FYM required the minimum number of PTU to attain 50 per cent flowering (15030), silking (17554) and harvest stage (19282). Crop which received the highest amount of either FYM or inorganic nitrogen required minimum number of helio-thermal units for attaining various phenophases. Pheno-thermal index gradually increased with the increase in fertility level either through or inorganic fertilizer for attaining silk and harvestable stage. Summer maize fodder with good nutritional status can utilize the thermal heat and radiation more efficiently.

Keywords: Fodder maize; nitrogen; FYM ; heat units

INTRODUCTION

Maize crop with desirable traits such as high dry matter content and free from anti-quality compounds unlike sorghum which contains hydrocyanic acid and sometimes proves to be toxic if fed too early so it is the most nutritious, succulent and palatable fodder crop amongst the cereals grown for this purpose during the summer season (March-September). Among all the nutrients nitrogen is generally most limiting under Punjab conditions. It plays a pivotal role in plant growth and development such as photosynthesis. Nitrogen is an essential component of tetrahedral structure of chlorophyll. As photosynthesis is essential for formation of glucose so nitrogen being an important constituent is essential for plant growth. Nitrogen is also an essential component of amino acids, several vitamins such as biotin, thiamine, niacin, riboflavin and is involved in several enzymatic reactions in plant. It is an essential part of nucleic acids DNA and RNA and hence it is the key element for obtaining high yields in maize. Positive response of maize to nitrogen fertilizer has been reported by Aflakpuri et al (1997) and Aslam et al (2011). Farm yard manure is the major source of soil organic matter in the intensive cropping system. The crop growth is the result of many physiological processes which are dependent on genetic make of the plant and environmental factors including soil fertility. Essential plant nutrients provide raw material to the plant for its skeleton build up and production of its food through the process of photosynthesis. The rate of photosynthesis is dependent on the ability of the plant to capture solar radiation for utilization in its favour. The rate of various physiological processes occurring within the plant is governed by thermal energy available to the plant. A healthy plant experiencing no limitation of any growth factor such as essential plant nutrients and moisture is able to harness the maximum thermal energy from solar radiation within the range of optimum temperature. This implies that these environmental factors interact with each other. Favorable weather conditions enable the plant to utilize the other factors of production such as plant nutrients more efficiently and in turn other external factors of production make the plant more efficient user of thermal energy received from the sun. There is great need to measure the interaction between these two assets of production. Therefore an experiment was conducted at Punjab Agricultural University, Ludhiana to study the effect of variable soil fertility levels and sources of plant nutrition to differential behavior of fodder maize for thermal energy utilization measured in terms of growth and development of the crop.

MATERIAL and METHODS

The experiment was conducted at research farm of Department of Agronomy, Punjab Agricultural University, Ludhiana during Kharif season of 2011 to study the effect of variable soil fertility levels and sources of plant nutrition to differential behavior of fodder maize for thermal energy utilization measured in terms of growth and development of the crop. The experiment was laid out in split plot design comprised of three farm yard manure levels in main plots (0, 12.5 and 25 tons/ha) and four nitrogen levels in sub-plots (0, 40, 80 and 120 kg/ha). Plant samples were collected at 30, 45, 60 days and harvest stage of summer fodder and leaf area index and dry matter accumulation were recorded. Agro-climatic indices namely growing degree days, helio-thermal units, photo-thermal units and phenol-thermal were recorded. Growing degree days or heat units were determined as per Nuttonson (1955):

$$\text{Growing degree days } ({}^{o}\text{C days}) = \frac{(T_{max} + T_{min})}{2} - T_b$$

where

T_{max}= Daily maximum temperature (^{o}C)
T_{min}= Daily minimum temperature (^{o}C)
T_{b}= Base temperature (10^{o}C)

The helio-thermal units (HTU), the product of GDD and corresponding actual sunshine hours for that day were computed on daily basis and summed up:

$$\text{Accumulated HTU} = \sum_{i=1}^{n} \text{GDD x Actual sunshine hours}$$

The photo-thermal units (PTU), the product of GDD and corresponding day length for that day were computed on daily basis and summed up:

where
Day length refers to maximum possible sunshine hours.

$$\text{Accumulated PTU} = \sum_{i=1}^{n} \text{GDD x Day length}$$

Growing degree days, helio-thermal units and photo-thermal units were accumulated from the date of sowing to each date of sampling and a particular date of phenophase to give accumulated indices.

Pheno-thermal index (PTI), the ratio of degree days to the number of days between two phenological stages were calculated as:

$$\text{Phenothermal index} = \frac{\text{Degree days consumed between two phenological stages}}{\text{\# days between two stages}}$$

The weekly meteorological data during the crop growing season were recorded and have been given in Fig 1.

RESULTS and DISCUSSION

Effect on growing degree days

Farm yard manure (FYM) and nitrogen levels caused variation in growing degree day requirement of the crop. Crop which received neither nitrogen nor FYM needed more number of degree days to attain a particular growth stage (Table 1). Increasing level of either FYM or nitrogen lowered the GDD requirement over the lower level because addition of FYM and nitrogen is known to promote vegetative growth so decreased the time gap between development stages and required less number of degree days to attain particular stage than those which neither received FYM nor nitrogen . The trend was uniform during all growth stages. This indicates that improvement in fertility level either through

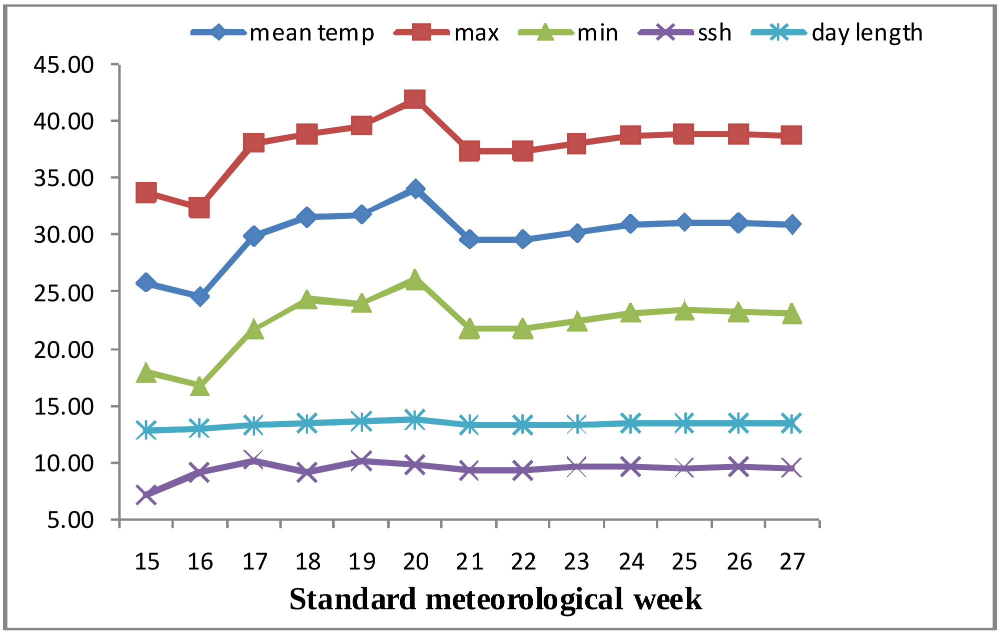

Fig 1. Mean weekly meteorological data during the crop growing season

the FYM or inorganic fertilizer made the crop to attain the growth stages earlier by decreasing the degree days requirement of the crop as FYM or nitrogen application enhanced the vegetative growth than those which neither received FYM nor nitrogen so consumed more number of degree days to attain particular stages. According to growing degree days concept higher the daily temperature shorter the crop duration; lower the temperature longer the crop duration. Now a days it is well established that sensitivity of the modern cultivars to temperature and photoperiod is decreasing and they are becoming day neutral and thermo-period insensitive. Crop growth is not only dependent on prevailing atmospheric temperature but also on essential plant nutrients. According to Liebig's law of minimum the crop growth is limited by the growth factors which are available in minimum. The atmospheric temperature during the crop season remained within the optimum range (20^{o}C) therefore the plant growth was directly proportional to soil fertility.

Effect on photo-thermal units

It is evident from the data presented in Table 2 that the crop which received the highest quantity (25 tons) of FYM required the minimum number of PTU to attain 50 per cent flowering (15030), silking (17554) and harvest stage (19282) whereas for the crop which received no FYM corresponding values were 17555, 19824

Table 1. Effect of fertility levels and source on accumulated growing degree days (°C day) consumed for attaining different phenological stages by summer maize fodder

Treatment	Accumulated growing degree days (°C days) at		
	50% tasseling	Silking	Harvest
FYM (tons/ha)			
0	1288	1448	1641.3
12.5	1182	1356.4	1515.2
25	1109	1287.7	1409.5
Nitrogen (kg/ha)			
0	1265	1427	1682.5
40	1204	1373	1605.4
80	1159	1312.9	1494.4
120	1109	1287.7	1427

Table 2. Effect of fertility levels and source on accumulated photo-thermal units (°C days) for attaining different phenological stages by summer maize fodder

Treatment	Accumulated photo-thermal units (°C days) at		
	50% tasseling	Silking	Harvest
FYM (tons/ha)			
0	17555	19824	22565
12.5	16052	18523	20777
25	15030	17554	19282
Nitrogen (kg/ha)			
0	17233	19531	23154
40	16366	18761	22059
80	15730	17909	20485
120	15031	17555	19531

and 22565. The crop which received 12.5 tons FYM behaved in between these two treatments. Increasing the nitrogen level from 0 to 120 kg/ha was observed to decrease the PTU requirement during the crop season. Each level of nitrogen lowered the PTU requirement for attaining a particular growth stage by about 4-5 per cent over the lower level. A photo-thermal unit is a product of growing degree days and total length of the day. As has been discussed in previous section on GDD better crop growth with enhanced fertility lowered the GDD requirement hence the effect was similar on its product also.

Effect on helio-thermal units

A perusal of data presented in Table 3 on helio-thermal unit of the crop reveals that farm yard manure and nitrogen levels brought out variation in helio-thermal unit requirement of the crop. Crop which received the highest amount of either FYM or inorganic nitrogen required minimum number of helio-thermal units for attaining various phenophases. As fertility level was increased progressive decrease in HTU requirement was observed. Helio-thermal unit is a product of the growing degree day and the bright sunshine hours on corresponding day. Whereas growing degree day is the measure of relative warmth during growing season and duration of sunshine hours determines the availability of solar radiation for photosynthesis. In fact most of the plants are able to manufacture their food through the process of photosynthesis in the presence of sunlight only. Longer the day length more is the period of availability of solar radiation. Increasing the fertility levels either through FYM or urea was found to enhance the leaf area index. Leaves are responsible for capturing the solar radiation and carrying out photosynthesis. Higher leaf area index under increased fertility levels might have helped the plant in harnessing more solar radiation and thus stimulated the plant growth.

Effect on pheno-thermal index

Pheno-thermal index (PTI) is the ability of the plant to utilize thermal heat for its development. Its higher value indicates better efficiency of the plants. Data on pheno-thermal index are presented in Table 4. It was be observed that the pheno-thermal index gradually increased with the increase in fertility level either through organic or inorganic fertilizers for attaining silk and harvestable stage however for attaining tasseling stage reverse trend was observed. It decreased from lower fertility level to higher fertility level however it increased from tasseling to maturity onwards. Crop which received neither nitrogen nor FYM had higher pheno-thermal index value (Table 4). Increasing levels of either FYM or nitrogen lowered the PTI requirement because degree days consumed as well as number of days between two stages also decreased and crop acquired the different stages earlier than the crop which neither received FYM nor nitrogen hence having highest PTI requirement. The trend was uniform during all growth stages. This indicates that improvement in fertility level either through the FYM or inorganic fertilizer enhanced the vegetative growth of crop and therefore decreased the PTI requirement of the crop by decreasing the number of days between two stages of the crop than those which neither received FYM nor nitrogen during its entire growth.

Table 3. Effect of fertility levels and source on accumulative helio-thermal units (°C day) consumed for attaining different phenological stages by summer maize fodder

Treatment	Accumulated helio-thermal units (°C days) at		
	50% tasseling	Silking	Harvest
FYM (tons/ha)			
0	12398	13325	14244
12.5	11301	12853	13749
25	10509	12397	13077
Nitrogen (kg/ha)			
0	12164	13078	14417
40	11521	12897	14010
80	11055	12657	13720
120	10509	12397	13077

Table 4. Effect of fertility levels and sources on photo-thermal index (°C days/day) between different phenological stages of summer maize fodder

Treatment	Photo-thermal index (°C days/day) at		
	50% tasseling	Silking	Harvest
FYM (tons/ha)			
0	19.81	20	19.33
12.5	19.7	19.88	19.85
25	19.45	21.24	20.3
Nitrogen (kg/ha)			
0	19.76	21.14	19.65
40	19.73	21.72	20.8
80	19.64	21.98	21.35
120	1912	22.33	22.76

Effect on periodic heat use efficiency

Heat use efficiency indicates ability of the plant to produce dry matter per unit of heat use. An improvement in the heat use efficiency was observed with the increase in fertility level and advancement of the crop stage. Heat use efficiency of 30 days old crop was minimum 3.05 with no FYM and it increased to 3.20 and 6.43 at 45 and 60 days after sowing (Table 5). This value increased with increase in FYM level to 12.5 and 25 tons/ha which was 3.10 and 3.50 kg/ha/°C indicating that improvement in the crop growth with the higher FYM

Table 5. Periodic heat use efficiency (kg/ha °C day) of summer maize fodder under different treatments

Treatment	Heat use efficiency (kg/ha °C day) at			
	Days after sowing			Harvest
	30	45	60	
FYM (tons/ha)				
0	3.05	3.20	6.43	4.86
12.5	3.10	3.53	6.37	5.71
25	3.50	4.18	6.76	6.46
Nitrogen (kg/ha)				
0	3.07	3.12	5.76	4.67
40	3.12	3.31	6.35	5.26
80	3.26	3.79	6.65	5.90
120	3.41	4.32	7.33	6.46

level and advancement of the crop growth enhanced the ability of the plant to utilize thermal heat for its development. Heat use efficiency was observed to improve with the increase in nitrogen level and advancement of the growth stage.

CONCLUSION

The study revealed that a healthy crop with good nutritional status can utilize the thermal heat and radiation more efficiently than a crop with poor nutritional status which indicates that thermal indices of a crop can vary in response to nutritional status.

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