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Study on physiological growth parameters in maize hybrid germplasm lines under moisture deficit stress

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Abstract
A field experiment was conducted on maize (*Zea mays*) at EB-II section of the Department of Plant Breeding and Genetics, College of Agriculture, OUAT, Bhubaneswar. The twelve germplasm lines along with 3 hybrid checks were evaluated under drought conditions. The plant dry weights were recorded from 45 Days after sowing with 10 days interval till harvest and using that data RGR, CGR, NAR and LAI were calculated and illustrated in the form of graphs. The present research emphasises on the growth of the maize hybrid germplasm lines under receding soil moisture condition and a significant variation was observed regarding all the growth parameters at all the growth stages. LAI ranges from 2.60 (NK6204 at 60DAS) to 5.39 (Z630-2 at 75 DAS). CGR ranges from -1.32 (Z638-2 at 90 DAS) to 11.41 (PIO3396 at 75 DAS). RGR ranges from 5.08 (Z638-3 at 90 DAS) to 5.67 (Z638-1 at 90 DAS). NAR ranges from -0.28 (Z638-2 at 90 DAS) to 2.91 (900MGold at 75 DAS). There were some reports that LAI reduction as a drought mitigating strategy the germplasm lines with lower LAI show tolerance towards drought as in case of the three check hybrids, Z638-3 and Z637-1 germplasm lines. The reduced Stover yield and grain yields in all the germplasm lines and the three hybrid checks were due to the drought stress imposed from 45 DAS to 75 DAS. The germplasm line Z635-3 (2.65 t ha^{-1}) is considered to be drought-tolerant among the 12 germplasm lines because of its yield potential under drought conditions.

Keywords: Maize, moisture stress, germplasm and physiology

Introduction
Maize is one of the most important cereal crops grown worldwide which occupies second place in terms of acreage and is known as the 'Queen of Cereals'. 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) [10]. The world production of maize stood at approximately 1040 million MT in the year 2016- 17 to which India contributes around 2% with 26 million MT in 2016-17. Agriculture in India is highly climate dependent because most of the farmers depend on rain for irrigating their crop lands. A prolonged dry spell without rain leads to Drought conditions during which the crop production is reduced drastically. Drought is a serious condition that also inhibits the nutrient uptake resulting in poor quality produce. Heisey and Edmeades (1999) [11] estimated that 20–25% of global maize area is affected by drought in any given year.

The vegetative growth potential, photosynthetic efficiency and drymatter partitioning are the main indicators of physiological indices. Growth is one of the vital functions of plant and Growth parameters such as leaf area index, relative growth rate, crop growth rate and net assimilation rate are very important in assessing crop growth and may be an indication of potential productivity especially since cultivars having balanced vegetative growth under stress leads to better economic returns (Khan *et al*., 2005) [13]. Reduction in leaf area under drought stress conditions is employed as adaptive strategy by maize plants. Considering this fact, leaf area index has been taken as an important consideration for maize breeding against drought stress (Hajibabaee *et al*. 2012) [8]. Crop growth rate is a radiation interception dependent growth parameter which primarily depend on the amount of radiation received by crop and also the amount of radiation that is utilized. Net assimilation rate is a radiation use efficiency of the crop it is highly dependent on the leaf area index. Net assimilation rate is maximum at the crop growth rate at which the leaf area is maximum and the light intercepted is not being inhibited by the shadow of the other leaves ie. It is also dependent on the arrangement of the leaves the closely spaced crops under drought condition records the least amount of NAR.

Crop ageing reduces the RGR, as the plant parts added are structural tissues which are not metabolically active and have no role in photosynthesis. Moreover, due to shading of leaves by one another and ageing, reduces the photosynthetic activity and RGR as well. Although the quantity of plant dry matter increases with time, RGR reduces due to increase in construction tissues to growing tissue. Harvest index is a measure of the biomass that is partitioned or allocated to the economic part ie cob in case of maize. The harvest index (percentage of grain yield based on total dry matter yield), which is a measure for crop productivity of grain maize production, increased by up to 29 % under drought stress (Hutsch *et al*. 2015) [12]. Stover yield is the dry mass of the above ground part which reduces with the drought conditions. When grain yield is plotted against straw yield, the frequently resulting negative slope suggests that gains in grain weight approximately equal losses in straw weight (Evans, 1993). In the present study, the physiological growth parameters of twelve CYMMIT hybrid germplasm lines along with three checks were measured under drought conditions.

Materials and Methods

A field experiment was conducted during *Rabi* season 2015-16 at EB-II section of the Department of Plant Breeding and Genetics, College of Agriculture, OUAT, Bhubaneswar. It falls in the humid sub-tropical climatic zone of the state. The water deficit stress was imposed with in the field conditions by giving an irrigating gap of one 30 days from 45 days after sowing to 75 days after sowing. The field subjected to stress the dry weights were recorded and these physiological parameters were calculated with the following procedures.

Leaf area index

LAI is expressed as the ratio of the leaf area (A) (only one side) to the ground area (P) occupied by the crop. The formula adopted for determining leaf area index is furnished below (TN Carlson *et al*., 1997) [2].

$$\text{LAI} = \frac{\text{Total Leaf Area}}{\text{Ground Area}}$$

Net assimilation rate

NAR is defined as dry matter increment per unit leaf area per unit time and expressed as g m^{-2} day^{-1} (Gregory 1926).

$$\text{NAR} = \frac{W_2 - W_1 \times \text{Ln}\,(L_2 - L_1)}{(T_2 - T_1)(L_2 - L_1)}$$

Relative growth rate

Relative growth rate (RGR) is defined as the total plant dry weight increase in a time interval in relation to the initial weight or dry matter increment per unit biomass per unit time or milligram of dry weight increase per gram of dry weight increase per gram of original weight per unit time and expressed as unit dry weight / unit dry weight / unit time (g g^{-1} day^{-1}) (Leopold and Kriedemann 1975).

$$\text{RGR} = \frac{\text{Ln}W_2 - \text{Ln}W_1}{T_2 - T_1}$$

Crop growth rate

The CGR explains the dry matter accumulated per unit land area per unit time expressed in (g m^{-2} day^{-1}) (Watson, 1958). CGR of a species are usually closely related to interception of solar radiation.

$$\text{CGR} = \frac{W_2 - W_1}{T_2 - T_1}$$

Where, W_1 -dry weight of whole plant at time T_1; W_2= dry weight of whole plant at time T_2; L_1= leaf area at T_1; L_2= leaf area at T_2; T_2 - T_1 = time interval in days between initial and final observation.

Harvest index

Harvest index is defined as the ration of economic yield to total biological yield (Donald and Hamblin 1976) and expressed in percentage. The harvest index for maize was worked out as indicated below.

$$\text{Harvest index} = \frac{\text{Economical yield}(\text{t ha}^{-1})}{\text{biological yield}(\text{t ha}^{-1})} \times 100$$

Stover yield (t ha^{-1})

Stover yield was recorded after complete sun drying the stalks from each net plot and expressed in t/ha.

Grain yield (t ha^{-1})

At physiological maturity cobs from each net plot were harvested. Cobs were air dried, shelled, cleaned and weighed. Grain yield/ha was worked out and expressed in t/ha.

Results and Discussion

Leaf area index

Leaf area index is observed to be highest in Z638-1 (3.79) at 15 DASi followed by 4.94 and 4.80 at 75 DAS and 90 DAS respectively. Least LAI was observed in Z630-1 (2.98) at 15 DASi followed by 3.90 and 3.97 at 75 DAS and 90 DAS respectively. Other germplasm lines which recorded higher LAI are Z630-2 (5.39) followed by Z637-1 (4.98) and Z638-2 (4.45) respectively at 75 DAS. LAI showed a significant difference among the germplasm lines. Leaf area being the major photosynthetic apparatus has profound effect on the ultimate crop performance. Leaf area is reduced when the plants are imposed to moisture stress. In a similar fashion, the LAI was observed to reduce during the stress period (15 DASi) and increased at recovery period (75 DAS) and then decreased slightly at senescence phase (90 DAS). The highest LAI was recorded in the germplasm line Z638-1 at 15 DASi the LAI was positively associated with the yield in maize (Dow EW 1984; Recep C¸ akir 2004) [4, 1]. This implicates that the tolerant maize hybrid germplasm lines exhibited a subtle reduction in LAI thus conferring a greater photosynthetic advantage over susceptible ones. There were some reports that LAI reduction as a drought mitigating strategy the germplasm lines with lower LAI show tolerance towards drought as in case of the three check hybrids, Z638-3 and Z637-1 germplasm lines.

Crop growth rate (g m^{-2} d^{-1})

Crop growth rate was recorded at 75 DAS and 90 DAS, the highest value of crop growth rate was observed in the germplasm line Z630-4 (8.03 g m^{-2} d^{-1}) followed by 5.00 g m^{-2} d^{-1} at 90 DAS. The CGR was negative in Z638-2 and Z638-3. The germplasm lines with higher CGR are Z637-2(7.92 g m^{-2} d^{-1}), Z695-1(7.31 g m^{-2} d^{-1}) and Z630-2(7.11 g m^{-2} d^{-1}) respectively. Crop growth rate (CGR) was observed to be negative in two germplasm lines during the senescence phase (90 DAS) because of the translocation of the dry matter to the cob which act as a sink in the same pattern as observed in case of NAR (M.M. Haque and A. Hamid, 1998). Stress induced negative growth responses.

Relative growth rate (mg g^{-1} d^{-1})

Relative growth rate was recorded at 75 DAS and 90 DAS, the highest value of crop growth rate was observed in the germplasm line Z638-1 (5.62 mg g^{-1} d^{-1}) followed by 5.67 mg g^{-1} d^{-1} at 90 DAS. RGR was observed to be least in Z638-3 (5.12 mg g^{-1} d^{-1}). The germplasm lines with higher RGR are Z630-2, Z695-3 and Z695-1 respectively. A significant decline in the Relative growth rate (RGR) was observed at 15 DASi and the subsequent growth days. The decrease in the RGR with moisture stress was corroborated with the work of Grzesiak *et al.* (2007) [7].

Table I: Effect of moisture deficit stress on Harvest Index, Stover yield and Grain Yield of Maize hybrid germplasm lines

Treatment	H. I (%)	Stover yield (t ha^{-1})	Grain Yield (t ha^{-1})
Z630-1	66.7 (-22)	3.37 (21.3)	2.43 (3.65)
Z630-2	58.2 (-7)	4.23 (1.2)	2.07 (17.82)
Z630-3	41.3 (24)	4.97 (-16.0)	1.88 (25.28)
Z630-4	53.0 (3)	3.63 (15.3)	1.92 (23.77)
Z637-1	49.7 (9)	3.56 (17.0)	2.37 (5.90)
Z637-2	57.9 (-6)	4.22 (1.4)	2.44 (2.91)
Z695-1	48.8 (10)	4.67 (-9.0)	2.22 (11.83)
Z695-2	39.1 (28)	5.75 (-34.3)	2.25 (10.63)
Z695-3	75.3 (-38)	3.57 (16.7)	2.65 (-5.21)
Z638-1	54.6 (0)	4.57 (-6.7)	2.35 (6.55)
Z638-2	73.4 (-35)	3.64 (14.9)	2.61 (-3.61)
Z638-3	70.3 (-29)	3.70 (13.6)	2.22 (11.84)
NK6240	62.1 (-14)	3.58 (16.5)	2.21 (12.13)
900M Gold	64.1 (-17)	3.98 (7.2)	2.33 (7.44)
PIO3396	54.6	4.28	2.52
SE(m)±	4.7	0.43	0.06
CD(0.05)	11.7	1.07	0.14
CV (%)	14.1	18.19	4.37

Values in parenthesis indicates % change over check

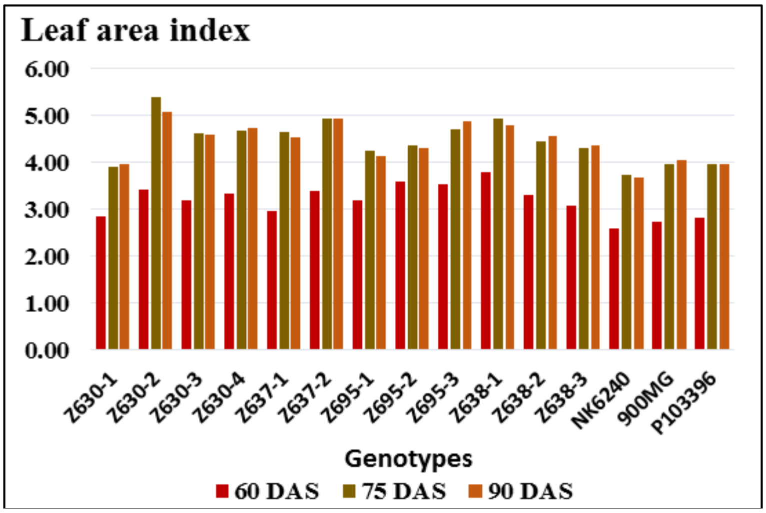

Fig 1: Effect of moisture deficit stress on LAI of Maize Hybrid germplasm lines

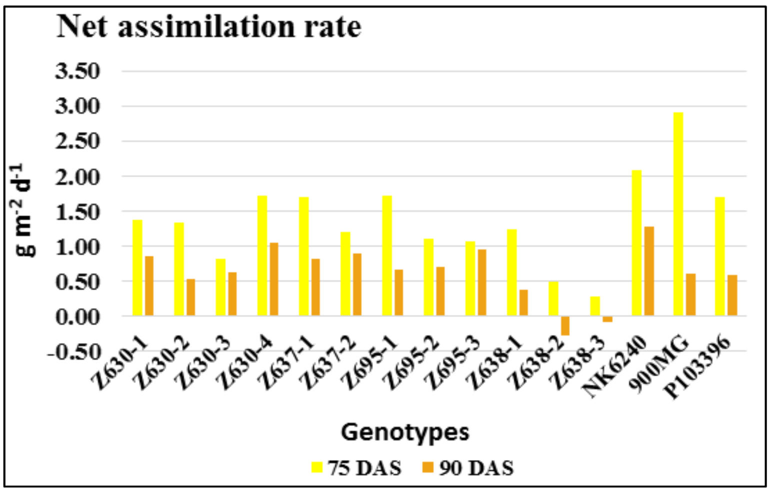

Fig 2: Effect of moisture deficit stress on NAR of Maize Hybrid germplasm lines

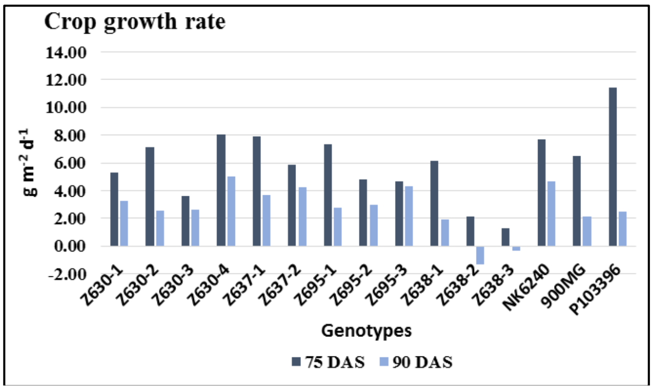

Fig 3: Effect of moisture deficit stress on CGR of Maize Hybrid germplasm lines

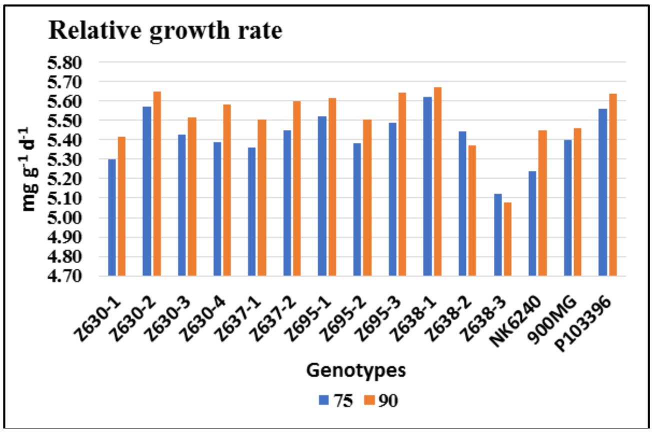

Fig 4: Effect of moisture deficit stress on RGR of Maize Hybrid germplasm lines

Net assimilation rate (g m^2 d^{-1})

Net assimilation rate was recorded at 75 DAS and 90 DAS, the highest value of net assimilation rate was observed in the germplasm line Z630-4 (1.71 g m^{-2} d^{-1}) followed by 1.06 g m^{-2} d^{-1} at 90 DAS. The RGR was negative in Z638-2 and Z638-3. The germplasm lines with higher RGR are Z695-1(1.72 g m^{-2} d^{-1}), Z630-2(1.34 g m^{-2} d^{-1}) and Z630-1 (1.37 g m^{-2} d^{-1}) respectively.

There was a reduction in the dry matter accumulation more than 25 % in all the germplasm lines including check hybrids because of the water stress given during the peak vegetative growth stage. The Stover yield was recorded maximum in the germplasm line Z638-1 (12.30) followed by Z630-2 (11.73) and Z695-1 (11.10) the percentage increase with the tolerant check 900M Gold is 24.3%, 18.54% and 12.24% respectively. The yield in tonnes/ha was recorded maximum in the germplasm line Z695-3 (2.65 tonnes/ha) the reduction in the grain yield was because of the water stress given during the reproductive development. That resulted in the pollen drying and grain filling was observed to be very meager which resulted in a severe yield loss.

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