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Full Length Research Paper

Effects of planting density and pattern on physiological growth indices in maize (*Zea mays* L.) under nitrogenous fertilizer application

Sayed Alireza Valadabadi and Hossein Aliabadi Farahani*

Islamic Azad University, Shahr-e-Qods Branch, Iran.

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Growth indices are useful for interpreting plant reaction to environmental factors. To evaluate the beneficial impact of planting density and pattern on induced maize (*Zea mays* L. cul. Single-cross 704) by nitrogenous fertilizer, this research was conducted at Iran and the experimental design was a split factorial on the basis of completely randomized block design with four replications. The combination of nitrogenous fertilizer including 520, 400 and 280 kg urea ha^{-1} were assigned to the main plots and the planting density (70000 and 90000 plant ha^{-1}) and the planting pattern treatment (one row and two rows planting) were factorially assigned to the subplots. Treatments significantly affected the total dry weight (TDW), leaf area index (LAI), relative growth rate (RGR) and crop growth rate (CGR). In this study, results showed that physiological growth indices were increased by high density, application of 520 kg urea ha^{-1} and two rows planting. Consequently, our finding may give applicable advice to farmers and agricultural researchers for management and proper use of nitrogenous fertilizer in farming of maize under different planting density conditions.

Key words: Planting density, nitrogenous fertilizer, planting pattern, physiological growth indices, *Zea mays* L.

INTRODUCTION

Plant population density has important effects on vegetative (Tetio-Kagho and Gardner, 1988a) and reproductive development of maize (Williams et al., 1965; Tetio-Kagho and Gardner, 1988b). Maize yield is low with low plant density because of little plasticity in leaf area per plant (Williams et al., 1968; Tetio-Kagho and Gardner, 1988b; Cox, 1996). Additionally, maize plants have small capacity to develop new reproductive structures in response to an increase in available resources per plant (Edmeades and Daynard, 1979; Loomis and Connor, 1996). On the other hand, if plant density is too high, the reduce of the availability of resources per plant in the period surrounding silking generates a marked fall in yield per plant that is not offset by the increase in the plants number (Andrade et al., 1999; Vega et al., 2001). Tollenaar (1989) found that high plant density produced an increase in total dry matter production and a decrease in harvest index and that optimum plant density was a trade off of both effects. Leaf area and the vertical leaf area profile influence the interception and utilization of solar radiation of maize crop canopies and, consequently, maize dry matter accumulation and grain yield. Rate of leaf expansion, maximum leaf area and rate of leaf senescence are important factors in the estimation of canopy photosynthesis in crop growth simulation models that compute dry matter accumulation from temporal integration of canopy photosynthesis. In addition to total leaf area, the area per leaf profile or the vertical distribution of leaf area is also required when the calculation of canopy photosynthesis is based on sunlit and shaded leaf area across various layers in the crop canopy (Boote et al., 1996). Leaf area is influenced by genotype, plant population (PP) (Murphy et al., 1996) climate and soil fertility. Some experiments have shown that a LAI between 3 and 4 may be optimal for achieving maximum yield (Lindquist et al., 1998). Also, increase in PP and row spacing at the same density reduce the leaf area index required to intercept 95% of the incident radiation due to an increase in the light extinction coefficient (Flenet et al., 1996). Crop growth rate is directly

*Corresponding author. E-mail: farahani_aliabadi@yahoo.com.

Table 1. The results of soil analysis.

Soil texture	Sand (%)	Silt (%)	Clay (%)	K mg/kg	P mg/kg	N mg/kg	Na Ds/m	EC 1: 2.5	pH	Depth of sampling
Clay Loam	39	34	27	145.2	4.2	36.7	0.04	0.18	8.0	0-30cm

related to the amount of RI (radiation intercepted) by the crop (Jeffrey et al., 2005). Dehdashti and Riahinia (2008) studied the effect of different row spacing and density of maize on total day weight (TDW), leaf area index (LAI), net assimilation rate (NAR) and crop growth rate (CGR). Plot treatments were row spacing (60, 75 and 90 cm). Split plot treatments were within row spacing (12, 14, 16 and 18 cm). An increase of plant population (PP) from 10.5 to 13.9 plants m^{-2} increased LAI, TDW and CGR, but decreased NAR.

Saberali (2007) investigated the effects of plant density and planting pattern on growth and physiological indices of maize (*Zea mays* L.). Plant density treatment was at two levels: Recommended plant density (70000 plant ha^{-1}) and 1/5 times recommended plant density (105000 plant ha^{-1}). Planting pattern treatment was at two levels: One and two rows planting (planting on both of ridge sides). The results showed that in high maize density, leaf area index, total dry weight and crop growth rate increased than low maize density in and throughout of growth season. Two row planting pattern also increased leaf area index, total dry weight and crop growth rate compare to one rows planting pattern, although, it does not have the same effect as plant density.

Nitrogen is the major nutrient that influence plants yield and protein concentration. When the amount of available soil Nitrogen limits yield potential, additions of nitrogenous fertilizers can substantially increase plants yield (Olson and Swallow, 1984; Grant et al., 1985). Nitrogen fertilization affects maize DM production by influencing leaf area development, leaf area maintenance and photosynthetic efficiency of the leaf area (Muchow, 1988). O'Leary and Rehm (1990) reported that maize DM increased linearly at three sites and curvilinearly at five sites with inconsistent maize quality responses to N rates. Cox et al. (1993) reported that, maximum economic DM for maize occurred at an N rate of about 150 $kgha^{-1}$. The objective of this study was to obtain the best of plant density and pattern for obtaining maximum physiological growth indices under nitrogenous fertilizer application.

MATERIALS AND METHODS

This study was conducted on experimental field of the Ishmael Abad station in Qazvin at Iran (36°15' N, 49°55' W; 1300 m above sea level) from 10 June to 20 October, 2005, with clay loam soil (Table 1). The mean annual temperature (27°C) and rainfall in the study area is distributed with an annual mean of 309 mm. The experimental design was a split factorial on the basis of completely randomized block design with four replication. The combination of nitrogenous fertilizer including 520 (N_1), 400 (N_2) and 280 (N_3) kg urea ha^{-1} were assigned to the main plots and the planting density (70000 (D_1) and 90000 (D_2) plant ha^{-1}) within row spacing were 14.8 (P_1) and 19.1 (P_2) cm, respectively and the plantting pattern treatment (one row and two rows planting) were factorially assigned to the subplots. The field was prepared in a 37.5 m^2 area (10 m × 3.75 m), a total of 48 plots of maize (*Zea mays* L. cul. Single-cross 704) was used in this experiment and row spacing was 75 cm. Initially, plant nutrient feed of phosphorus and potassium were added by applying 100 $kgha^{-1}$ triple super phosphate and 100 $kgha^{-1}$ K_2O after cultivation time, respectively. Nitrogenous fertilizer was added in four periods; application of 12.5% nitrogenous fertilizer treatment at cultivation time, application of 37.5% nitrogenous fertilizer 25 days after cultivation, application of 37.5% nitrogenous fertilizer 50 days after cultivation and application of 12.5% nitrogenous fertilizer in the beginning of flowering stage. In order to determine TDW, from 20 days after cultivation to harvesting time, 10 plants were selected randomly in all plots each 15 days regularly. Samples were placed under 75°C in electrical oven for 48 h and were weighed by electrical scale and then the values of TDW was determined in each sampling stage. To determine LAI in each sampling stage, leaves area of samples were estimated by leaf area meter before placing in oven. Finally, RGR and CGR were determined using the following formulas (Aliabadi et al., 2008):

$$RGR = \frac{LnW_2 - LnW_1}{T_2 - T_1}$$

Where:

$LnW_2 - LnW_1$ = Natural logarithm of dry matter variations;
$T_2 - T_1$ = Time variations as day.

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

Where:

$W_2 - W_1$ = Dry matter variations; $T_2 - T_1$ = Time variations as day;
GA = Ground area.

Finally, after determination of TDW, LAI, RGR and CGR, their graphs were designed using Excel computer software.

RESULTS

The final results showed that nitrogenous fertilizer significantly increased physiological growth indices in maize which indicates that the highest TDW (1910 $g.m^{-2}$), LAI (4.2), RGR (0.08 $g.g.day^{-1}$) and CGR (31.2 $g.g.m^{-2}.day^{-1}$)

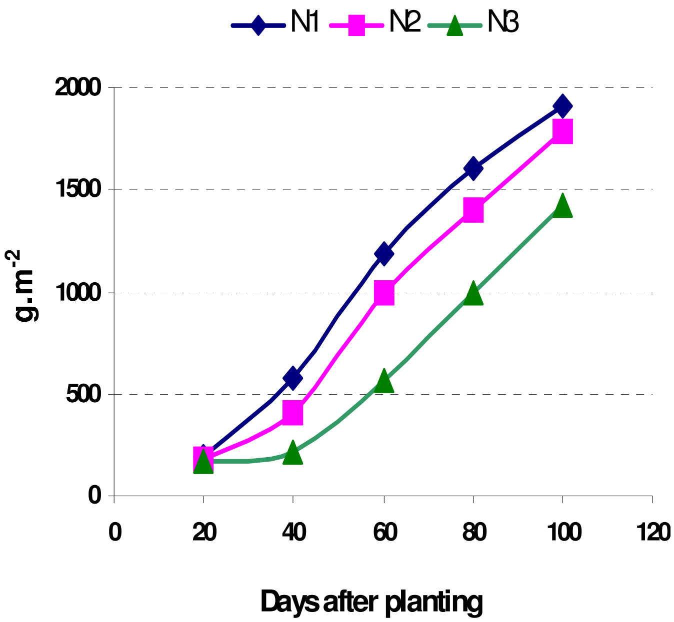

Figure 1. TDW variation under nitrogenous application.

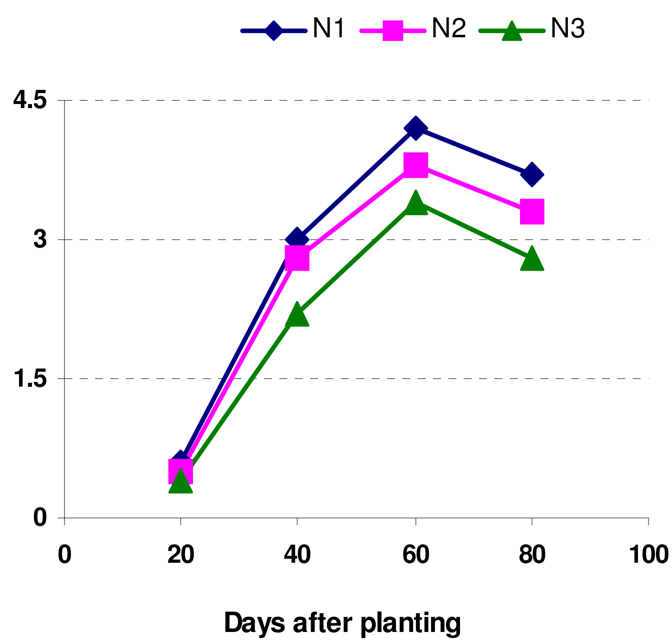

Figure 2. LAI variation under nitrogenous application.

were obtained by application of 520 kg urea ha^{-1}, respectively (Figures 1, 2, 3 and 4).

Also, our data indicated that high planting density increased physiological growth indices and highest TDW (1810 g.m^{-2}), LAI (4.4), RGR (0.075 g.g.day^{-1}) and CGR (34.1 g.g.m^{-2}.day^{-1}) were achieved by 90000 plant ha^{-1} (Figures 5, 6, 7 and 8). Also, our results showed that planting pattern increased physiological growth indices and highest TDW (1810 g.m^{-2}), LAI (4.4), RGR

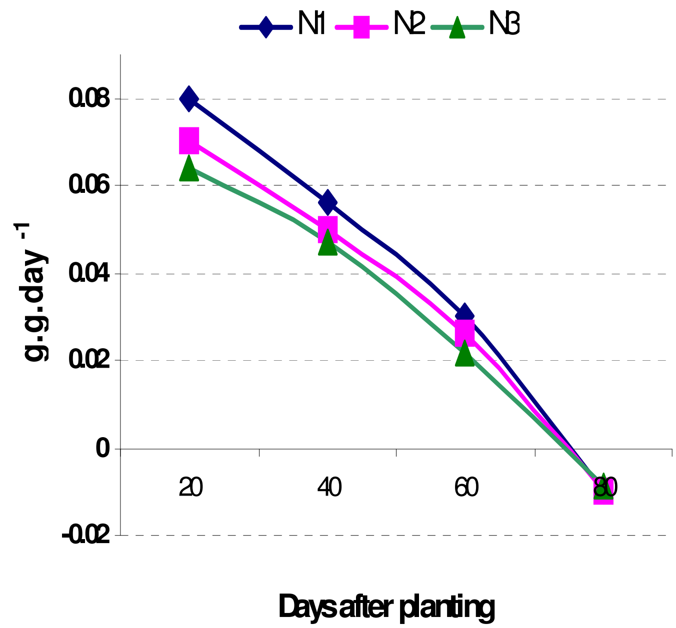

Figure 3. RGR variation under nitrogenous application.

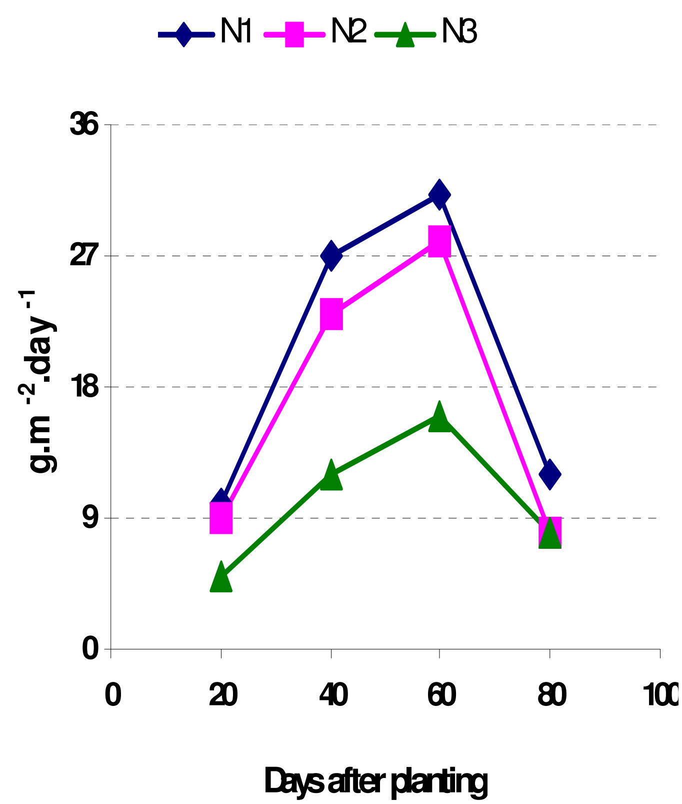

Figure 4. CGR variation under nitrogenous application.

(0.075 g.g.day^{-1}) and CGR (34.1 g.g.m^{-2}.day^{-1}) were achieved by two rows planting (Figures 9, 10, 11 and 12).

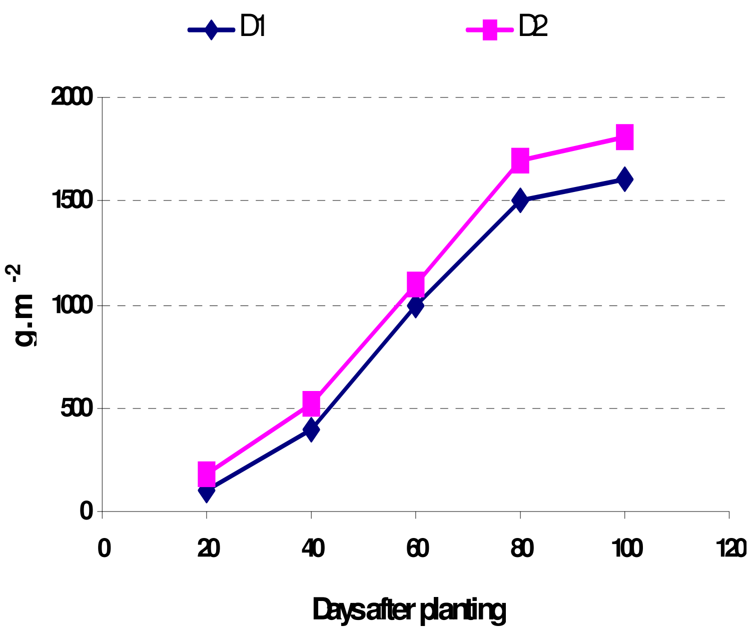

Figure 5. Effect of planting density on TDW.

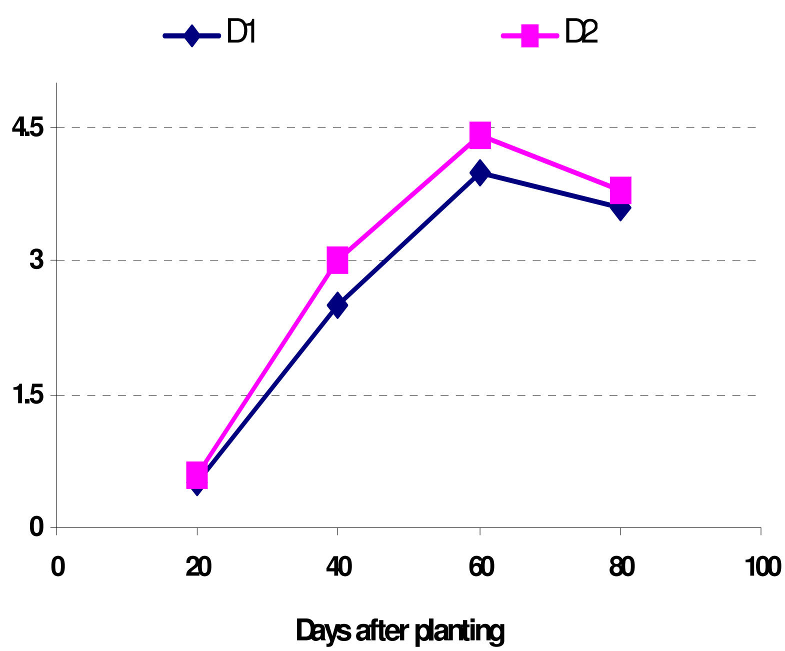

Figure 6. Effect of planting density on LAI.

DISCUSSION

Our final results indicated that application of nitrogenous fertilizer increased physiological growth indices of maize This is because the presence of nitrogen helps in developing leaf area and lateral stem as a result of the increase in the physiological growth indices. The interaction between the amount of the dry matter and leaf development is considered important as two components of the physiological growth indices, therefore, values of TDW and LAI increased under application of nitrogenous fertilizer sorely. Therefore, each increaser factor of TDW

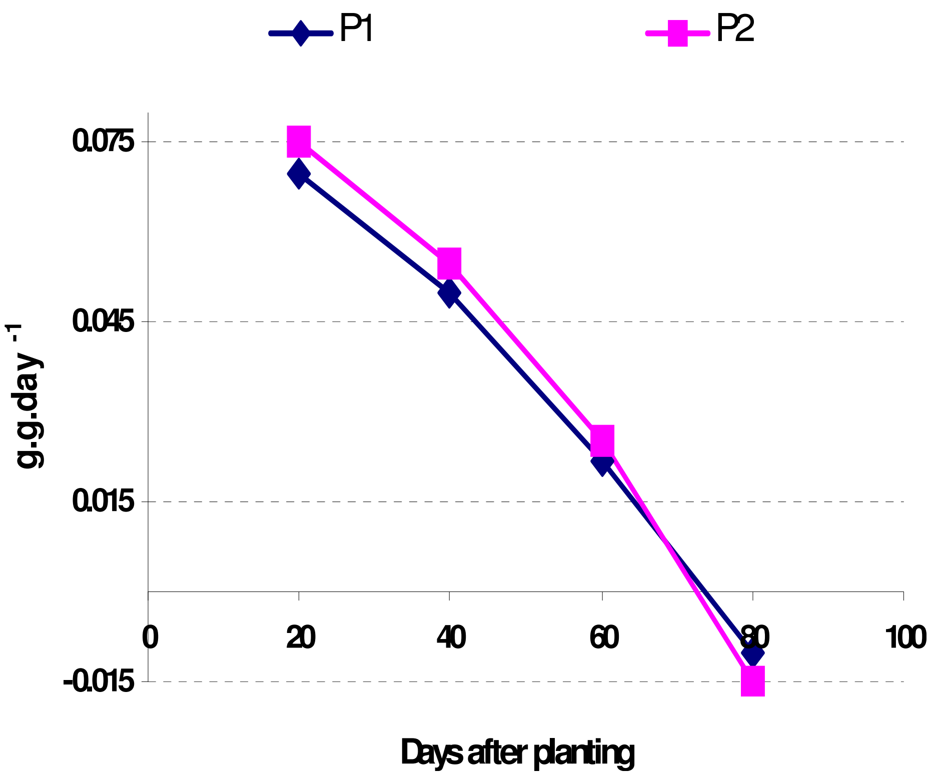

Figure 7. Effect of planting density on RGR.

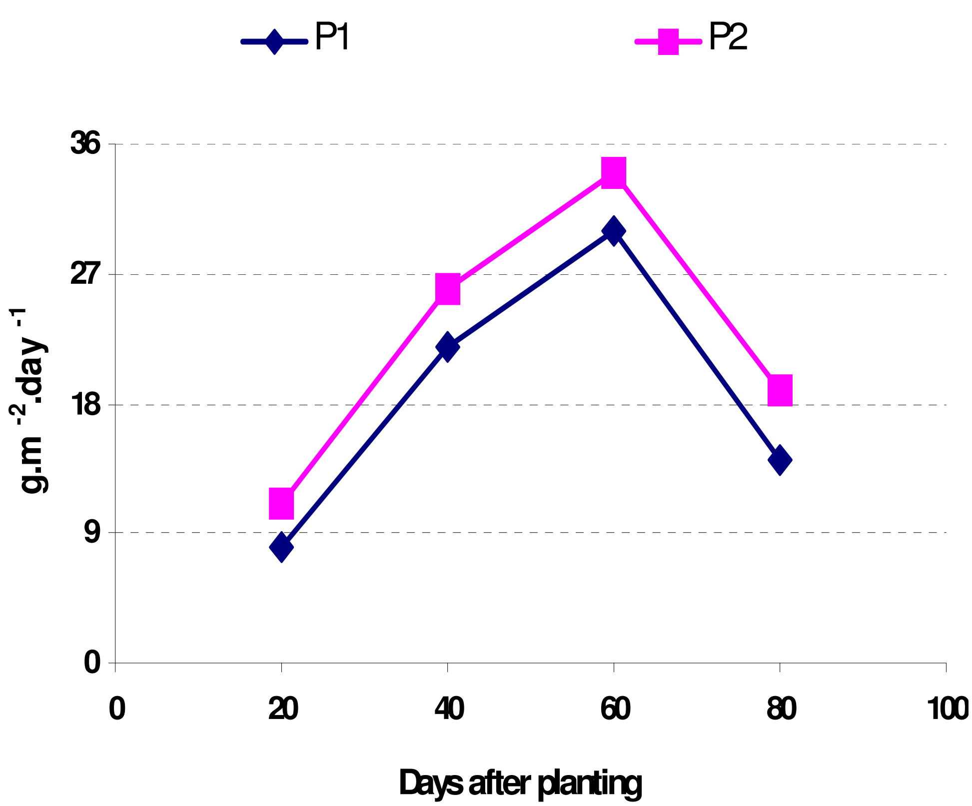

Figure 8. Effect of planting density on CGR.

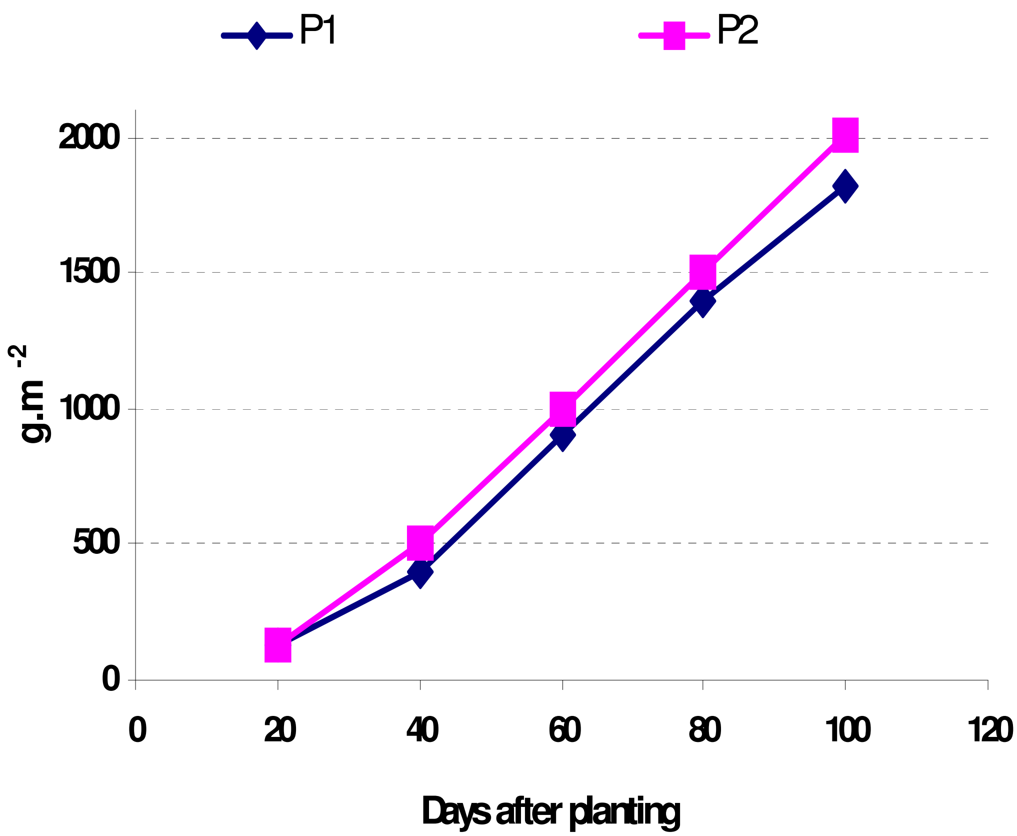

Figure 9. Planting pattern influence on TDW in maize.

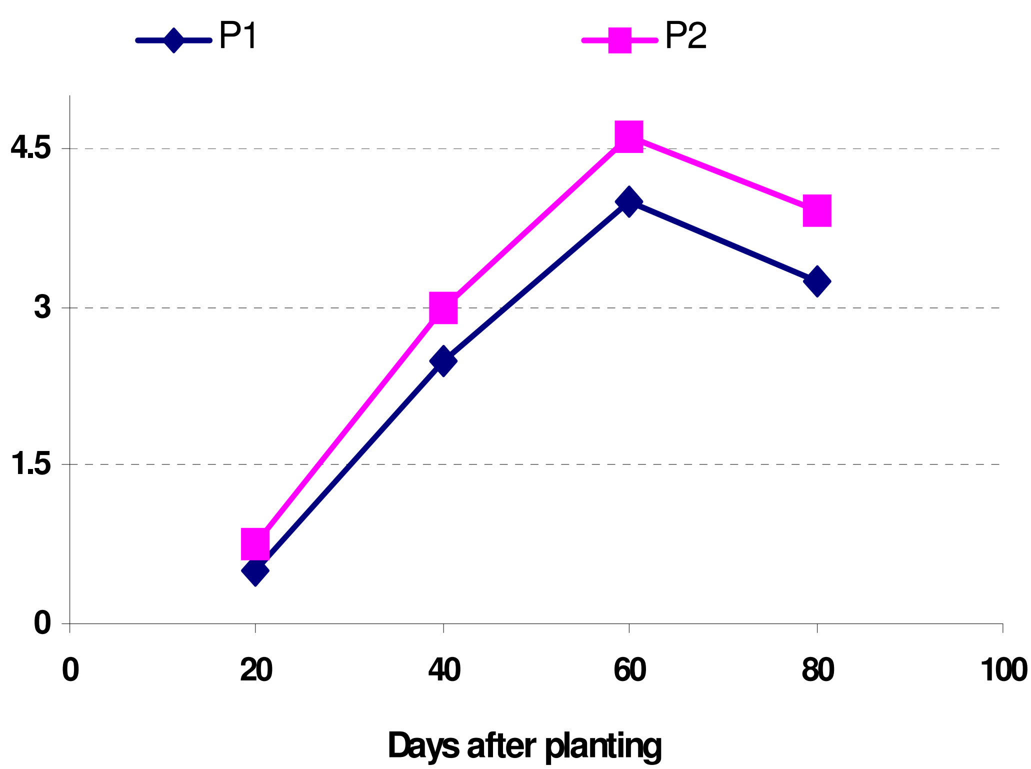

Figure 10. Planting pattern influence on LAI in maize.

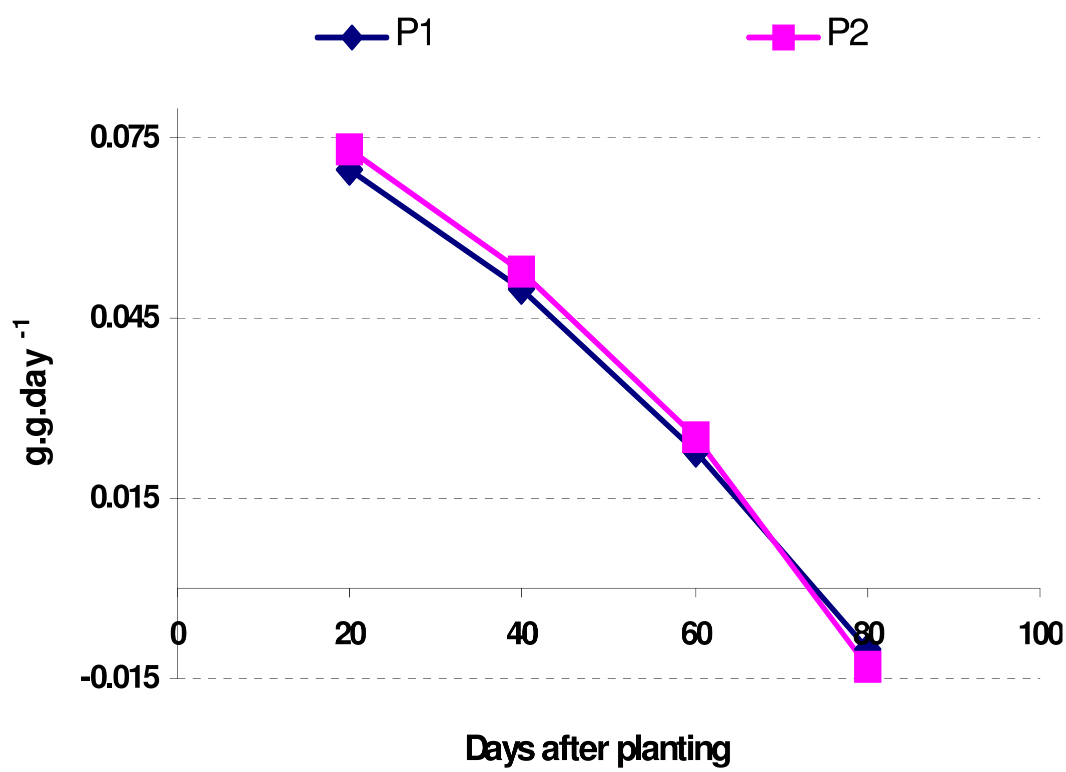

Figure 11. Planting pattern influence on RGR in maize.

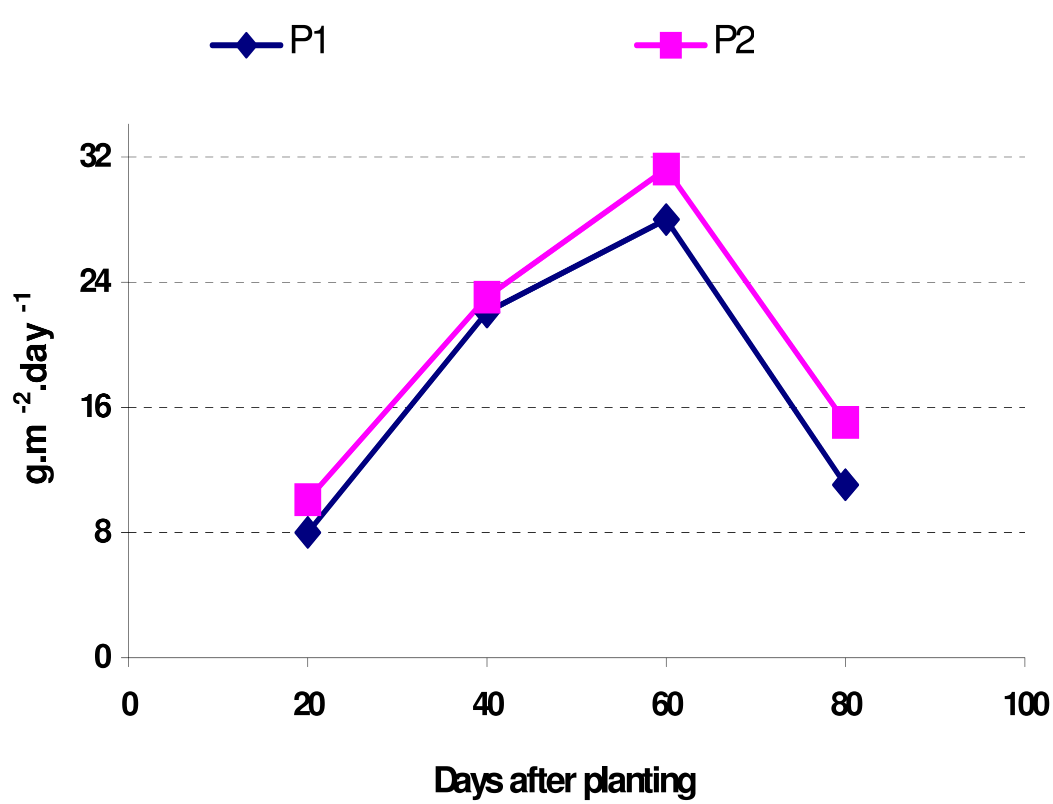

Figure 12. Planting pattern influence on CGR in maize.

and LAI, can increases RGR and CGR. The results showed that application of nitrogenous fertilizer increased total dry matter of maize, because nitrogen, which is a primary constituent of proteins, is extremely susceptible to loss when considering that average recovery rates fall in the range of 20 to 50% for dry matter production systems in plants, a main element in production. Also, the highest physiological growth indices were achieved under high plant density, because photosynthesis increases by development of leaves area and increases TDW. Plant population density has important effects on vegetative and reproductive development of maize. Physiological growth indices in maize are low with low plant density because of little plasticity in leaf area per plant. Additionally, maize plants have small capacity to develop new reproductive structures in response to an increase in available resources per plant.

Conclusion

The results showed that application of nitrogenous fertilizer increased the physiological growth indices of maize sorely. Therefore, careful estimate of nitrogenous fertilizer concentration can increases optimal use from nitrogenous fertilizer in sustainable agriculture. Also, our study showed that high planting density and two rows planting contributed to protect TDW against low photosynthesis efficiency by increasing LAI. Practically, findings may suggest farmers and researchers to consider carefully on estimate of nitrogenous fertilizer application in different planting density and pattern conditions as current challenge of scientist in global changes.

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