Original Research Article

Responses of physiological indices of forage sorghum under different plant populations in various nitrogen fertilizer treatments

Abstract

In order to evaluate physiological indices of forage sorghum in different plant densitirs and nitrogen levels, an experiment was conducted at Research Farm, Faculty of Agriculture, Islamic Azad University, Isfahan (Khorasgan) Branch, Isfahan, Iran. The main plots were plant densities, namely, 250000, 300000, 350000, and 400000 plants per ha, and four levels of nitrogen, namely, 0, 80, 160 and 240 kg N/ha were sub-plots. The field was under cultivation of barley during the previous winter. For all plant density treatments, from 25 days after plantation until 95 days after planting, the total dry matter trend increased gradually. The highest total dry matter was observed in 95 days after plantion which was related to 400000 plants per ha and 240 KgN/ha. Study the trend of variances of crop growth rate showed that in all treatments, the crop growth rate was low in the beginning of sampling, thereafter increased considerably up to 60 days after planting with a peak in 60 days after planting, then showed a declining trend after that. In all of plant density treatments, RGR decrease during plant growth and reached to a zero at 75-85 days after planting, and it reached into negative after these days until harvesting time. In different plant nitrogen levels, RGR trends also decrase during plant growth and reached to a zero at 40-60 days after planting. The maximum LAI was obtained for 400000 plants per ha and 160 kgN/ha. Study of trend of net assimilation ratio (NAR) showed that in all treatments, the NAR was stable in the beginning of sampling, thereafter showed a declinig trend that toward zero (90-95 days after planting).

Keywords= Physiological indices, Forage sorghum, Plant density, Nitrogen.

Introduction

Sorghum [*Sorghum bicolor (L.) Moench*] is a major cereal food crop in many parts of the world (Shahrajabian *et al*., 2011). Bourke (1984) reported the importance of measuring total dry weight, leaf area index (LAI), and crop growth rate (CGR). Crop growth depends on the ability of leaves to capture and use solar radiation, with that they can provide the energy to drive both CO_2 assimilation and water transpiration processes (Albrizio and Steduto, 2005; Seyed Sharifi *et al*., 2011). Bavec et al. (2007) noted that the most important photosynthesis acceptor-leaf area vary among cultivation measures and it is limited factor for creating exact growth in wheat. Morphological indexes such as leaf area and plant height complement plant growth quantitative analysis and enable the determination of the effects of the use of different crop management techniques (Poh *et al*., 2011; Shahrajabian *et al*., 2013). Gordon *et al*. (1997) showed that historically models of leaf area index (LAI) have varied both in their complexity and physiological implications. Growth analysis is a way to assess what events occurs during plant growth (Hokmalipour and Hamele Darbandi, 2011). Growth analysis is a suitable method for plant response to different environmental conditions during life (Tesar, 1984). The determination and growth analysis, interpretation of how species respond to a given environmental condition (Zare-Feizabady and Ghodsi, 2004). To compare the physiological responses of growth, analysis should be independent of environmental changes. For growth analysis, leaf area and dry weight measured parameters are mandatory and growth will follow through mathematical calculations (Paleg and Aspinal, 1981). Factors affecting growth dynamics such as dry matter accumulation, crop growth rate, relative growth rate and leaf area index are important investigations tools to faciliate the development of better agronomic management (Rahimzadeh *et al*., 2013). Hunt (1982) concluded that total dry matter compensation is influenced by crop growth rate, relative growth rate, relative leaf area growth rate and net assimilation rate. This trial was conducted to evaluate some physiological indices of forage sorghum in relation to different plant populations and nitrogen levels.

Materials and methods

The experiment was conducted in 2015 at Research Farm, Faculty of Agriculture, Islamic Azad University, Isfahan (Khorasgan) Branch, Isfahan, Iran (latitude 32^{o} 40$^{/}$N, longitude 51^{o} 58$^{/}$ E, and 1570 m elevation). The main plots were plant densities, namely, 250000, 300000, 350000, and 400000 plants per ha, and four levels of nitrogen, namely, 0, 80, 160 and 240 kg N/ha were sub-plots. The field was under cultivation of barley during the previous winter, and planting of sorghum was done just after harvesting of barley. In this trial, hybrid of forage sorghum, Speed Feed was used. Speed Feed is characterized by early flowering, early maturation, rapid and high accumulation of dry matter and high resistance to weeds and insects. The field was tilled to a depth of 20 cm. Previous crop was harvested on 21 June and forage sorghum seeds were sown on 24 June with skillful workers. Application of nitrogen fertilizer for each treatment was done in two stages (half of it was used before planting and half of it was used before stem elongation). The source of nitrogen fertilizer was urea. According to soil analysis and high amount of P and K, P and K fertilizers were not used. Also, weeds were controlled by hoe weeding. The first irrigation was applied immediately after sowing. Second irrigation was done three days after the first one. The other irrigation intervals were done according to plant 's requirement (10 days). Each plot has six rows, the length and width of each row was 4 and 3 m, respectveily. The distances between rows were 50 cm. Row numbers 1, 4 and 6 also upto 50 cm, primer and edge lines were discarded from sampling. Samples were harvested when plants were in 20% of anthesis stage. The variance trend of total dry matter (TDM), leaf area index (LAI), net assimilation ration (NAR), crop growth rate (CGR), and relative growth rate (RGR) were determined with using 1-5 equations (Acuqaah, 2002; Gupta and Gupta, 2005). Data were subjected to analysis by the SAS software and graphs were drwan using Excel program.

$$W= e^{a2+b2t+c2t\wedge 2} \quad (1)$$

$$LAI= e^{a1+b1t+c1\wedge 2} \quad (2)$$

$$NAR= (b2 + 2c2t)e^{(a2-a1)+(b2-b1)t+(c2-c1)t\wedge 2} \quad (3)$$

$$CGR= NAR*LAI= (b2 + 2c2t)e^{a2+b2t+c2\wedge 2} \quad (4)$$

$$RGR= b+2ct+3dt^{2} \quad (5)$$

Results and Discussion

Total dry matter

The influence of different nitrogen levels and plant densities on total dry matter trend was measured from 25 days after plantation until harvesting time. For all, plant density treatments, from 25 days after plantation until 95 days after planting, the total dry matter trend increased gradually. The highest total dry matter was observed in 95 days after plantion which was related to 400000 plants per ha (Fig 1). There was significant difference between 400000 plants per ha and other treatments. The minimum total dry matter was related to 250000 plants per ha. Study of trend of total dry matter shows that, this trend also increase slowly from 25 days after plantation until harvesting time. The highest and lowest total dry matter was obtained in 240 kgN/ha and control treatment (0 kgN/ha) which had meaningful differences with each other and other treatments (Fig 2). The increase in dry matter is related to accelerating the photosynthesis activity that is caused dry matter accumulation (Seyed Sharifi and Raei, 2011). These scientists also found that the efficiency of the conversion of inercepted solar radiation into dry matter decrease with decreasing of leaf area index. Total dry matter trend (TDM), and crop growth rate (CGR), are the most important traits in plant grwoth analysis (Hokmalipour and Hamele Darbandi, 2011).

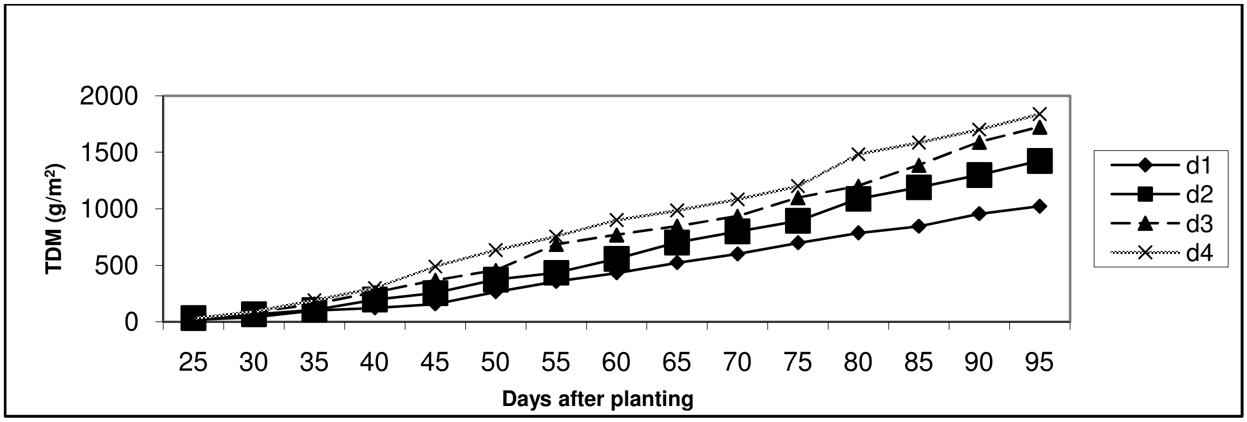

Figure 1. Total dry matter trend in different plant densities (d1, d2, d3 and d4 are 250000, 300000, 350000, and 400000 plants per ha, respectively).

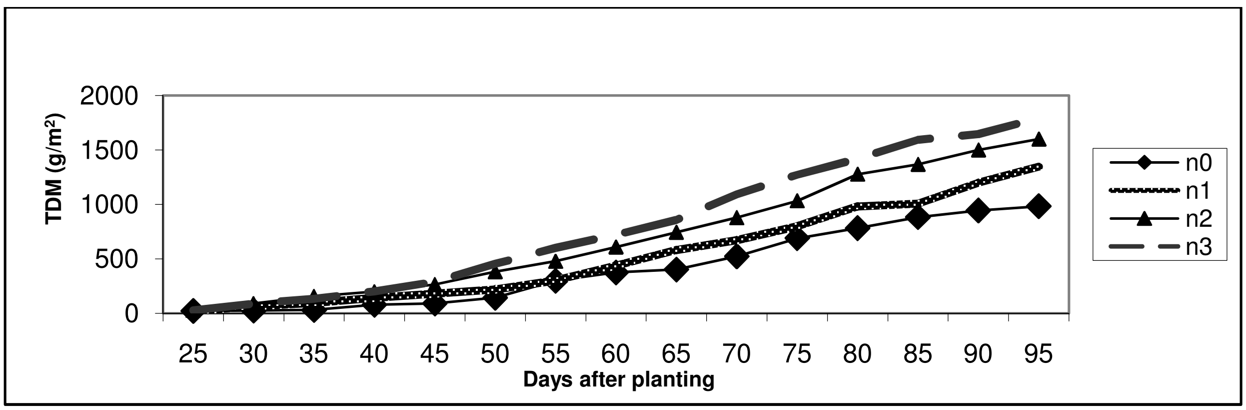

Figure 2. Total dry matter trend in different nitrogen levels (n0, n1, n2 and n3 are application of 0, 80, 160 and 240 kg N/ha).

Crop growth rate

The influence of different nitrogen levels on CGR trend has shown, CGR was low at 25 days after plantation, then the increased up to 50 days was happened. The highest CGR for d1, d2 and d4 was related to 50 days after plantation and the highest CGR for d3 was obtained in 55 days after plantation, then all trends decreased sharply (Fig 3). Study the trend of variances of crop growth rate showed that in all treatments, the crop growth rate was low in the beginning of sampling, thereafter increased considerably up to 60 days after planting with a peak in 60 days after planting for N0, N2 and N3, and 55 days after planting for N1, then showed a declining trend after that (Fig 4). The decrease in crop grwoth rate towards maturity is due to senescence of leaves and decrease of leaf area index (Seyed Sharifi and Raei, 2011). Beadle (1987) found that crop grwoth rate in early stages due to the complete absence of vegetation and low percentage of light absorption is lower, but with the rapid increase in the rate of plant growth that occurs because the level of developed leaves and thus absorption of solar radiation increase. Should be noted that negative values of crop grwoth rate is due to loss of leaves at the end of growing season (Hokmalipour and Hamele Darbandi, 2011).

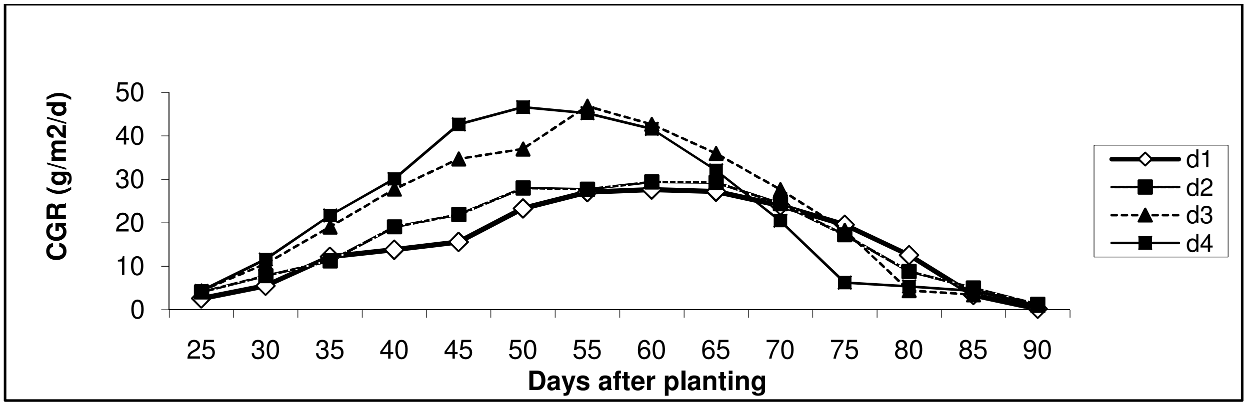

Figure 3. CGR trend in different plant densities (d1, d2, d3 and d4 are 250000, 300000, 350000, and 400000 plants per ha, respectively).

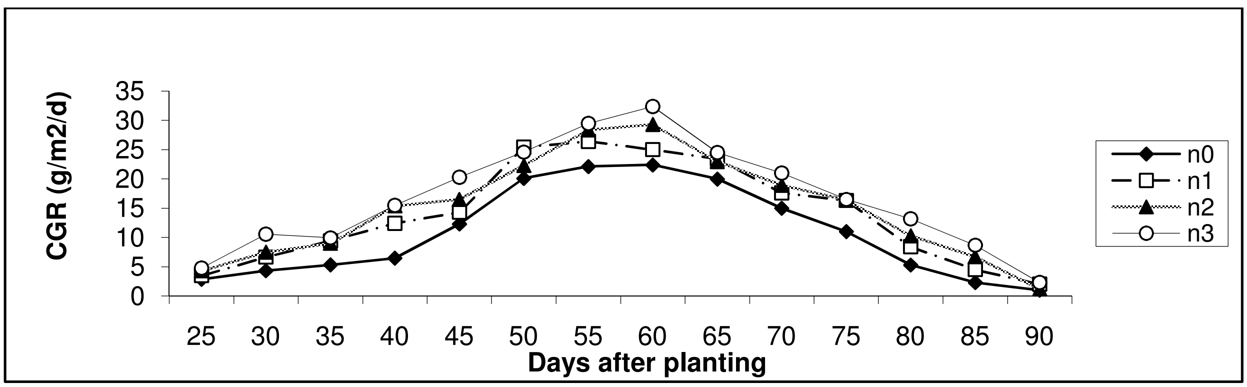

Figure 4. CGR trend in different nitrogen levels (n0, n1, n2 and n3 are application of 0, 80, 160 and 240 kg N/ha).

Relative growth rate

In the initial stages of the plant growth the ratio between alive and dead tissues is high and almost the entire cells of the productive organs are activity engaged in vegetative matter production (Seyed Sharifi *et al*., 2011). In all of treatment compunds, RGR decrease during plant growth and reached to a zero at 75-85 days after planting (Fig. 5), and it reached into negative after these days until harvesting time. In different plant nitrogen levels, RGR trends also decrase during plant growth and reached to a zero at 40-60 days after planting (Fig. 6). Similar observations have been reported by other researchers (Jeffery et al., 2005; Shahrajabian *et al*., 2013). Karimi and Siddique (1991) reported that variation in relative growth rate during the growth period is decreased, so that the high growth rate in the early period and then decreases. Relative growth rate of plants depends on environmental factors and genetic characteristics. Changes in the relative growth rate of plant photosynthesis and respiration changes with time, and thus, increasing the amount of plant respiration at the end of the period is negative (Robertson and Giunta, 1994).

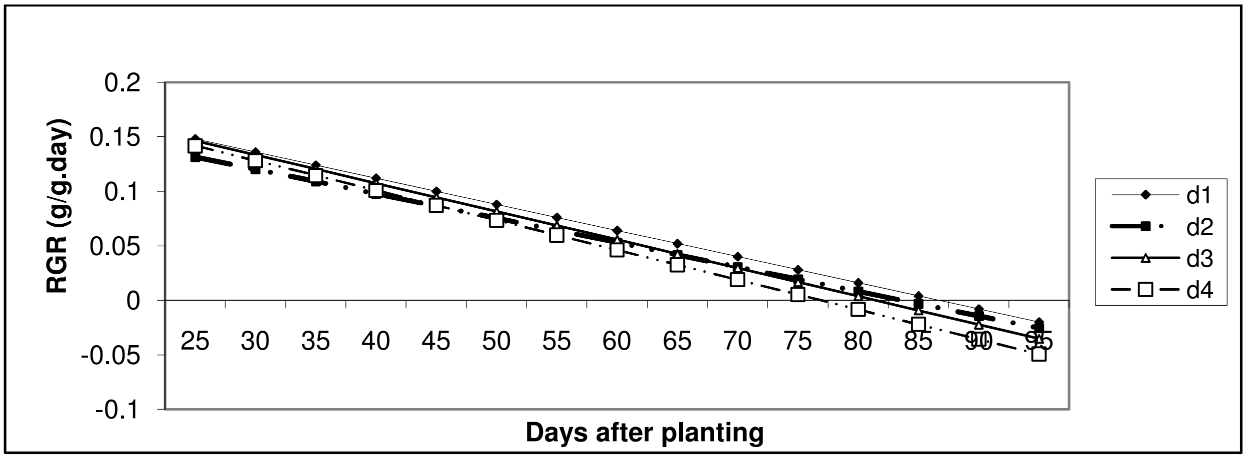

Figure 5. RGR trend in different plant densities (d1, d2, d3 and d4 are 250000, 300000, 350000, and 400000 plants per ha, respectively).

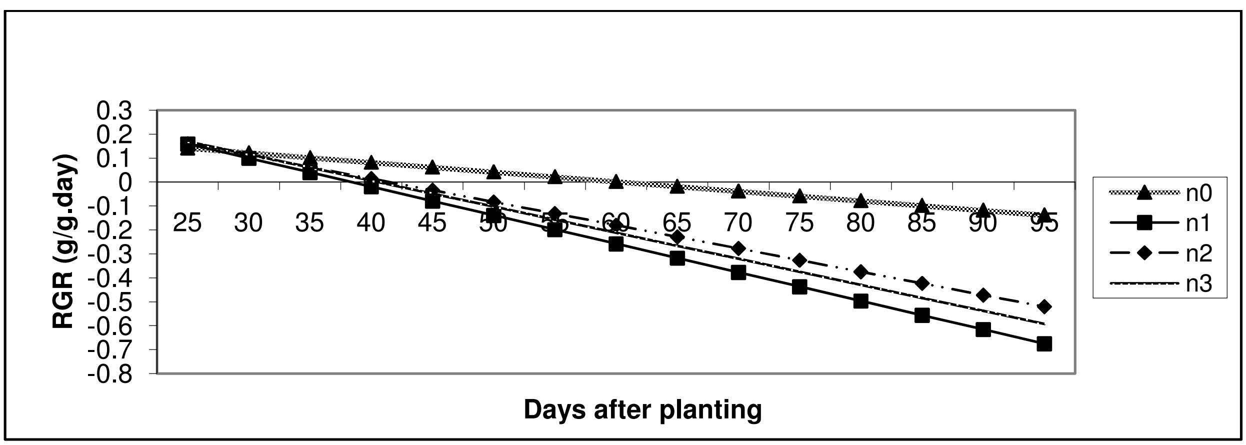

Figure 6. RGR trend in different nitrogen levels (n0, n1, n2 and n3 are application of 0, 80, 160 and 240 kg N/ha).

Leaf Area Index

LAI trend in all growth and development stages for different irrigation treatments were measured. Leaf area index increased during plant growth and reached to a maximum level at 90 days after planting. From 90 days after planting until harvesting time, leaf area index trend was steady due to increasing aging leaves, shading and competition between plants for light and other resources. The maximum LAI was obtained for d4 and N3, respectively. The lowest LAI was also achieved in d1 and N0 (control treatment). Leaf area index (LAI) is an index of the size of the photosynthetic system. Seyed Sharifi and Raei (2011) mentioned that increasing leaf area index is one of the ways of increasing the capture of solar radiation within the canopy and production of dry matter. Hence, dry matter produced decreases with decreasing of leaf area index.

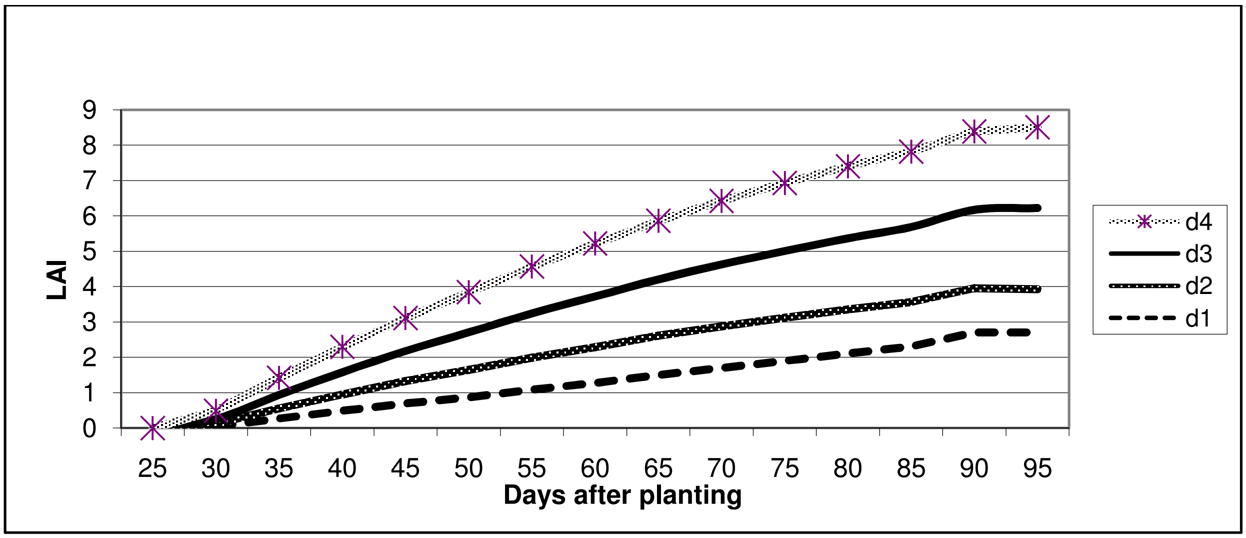

Figure 7. LAI trend in different plant densities (d1, d2, d3 and d4 are 250000, 300000, 350000, and 400000 plants per ha, respectively).

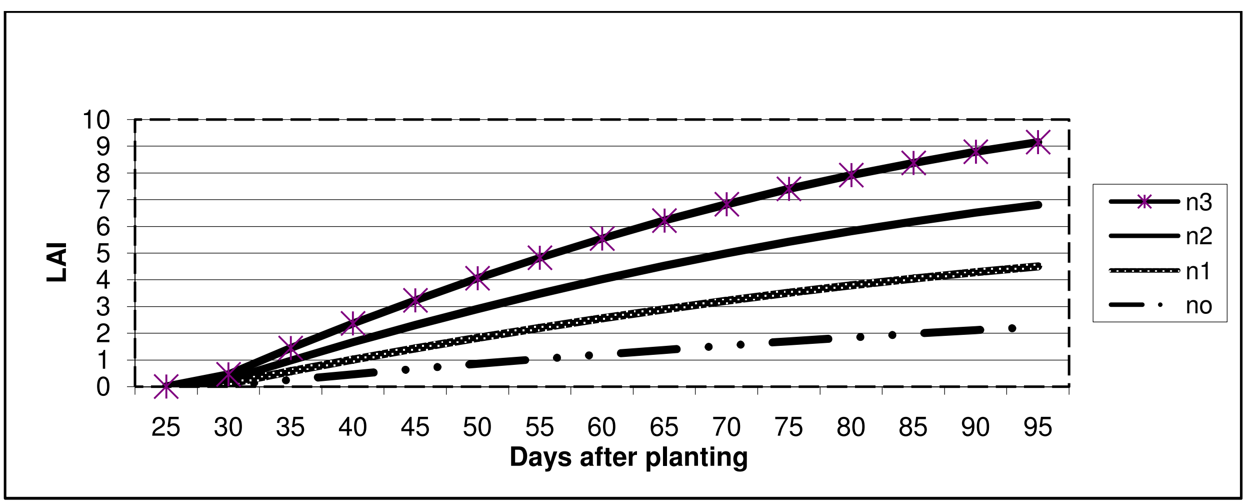

Figure 8. LAI trend in different nitrogen levels (n0, n1, n2 and n3 are application of 0, 80, 160 and 240 kg N/ha).

Net Assimilation Ratio

Study of trend of net assimilation ratio (NAR) showed that in all treatments, the NAR was stable in the beginning of sampling, thereafter showed a declinig trend that toward zero (90-95 days after planting). Net assimilation rate (NAR) is an indirect photosynthetic activity. This is based on the principle that the increase in dry weight of plants in a given period is a measure of net photosynthesis. Growth analysis is still the most simple and precise method to evaluate the contribution of different physiological processes in plant development (Seyed Sharifi and Raei, 2011). Shahrajabian et al. (2013) also indicated that physiological growth analysis is important in prediction of yield.

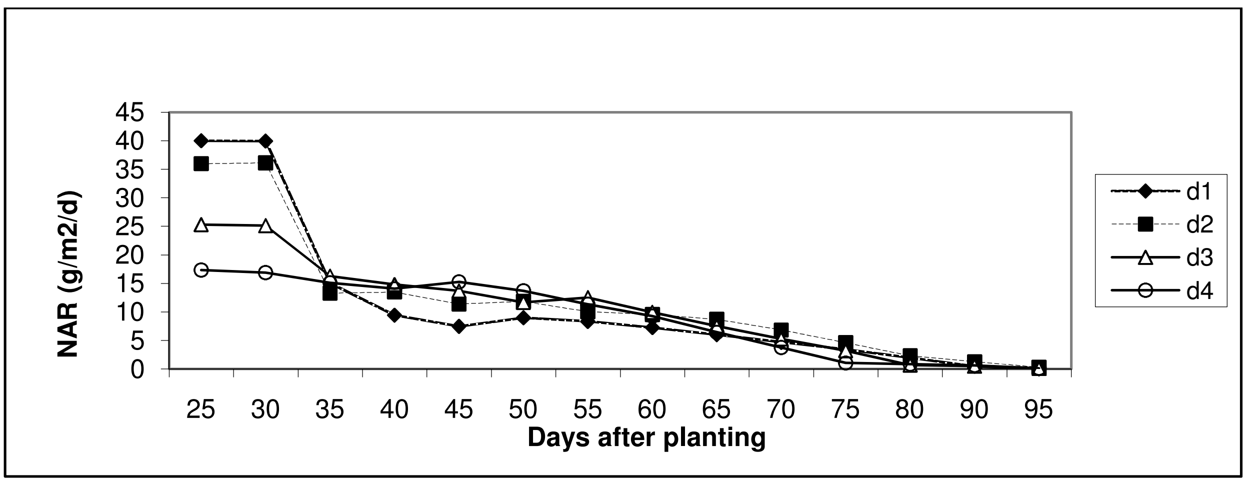

Figure 9. NAR trend in different plant densities (d1, d2, d3 and d4 are 250000, 300000, 350000, and 400000 plants per ha, respectively).

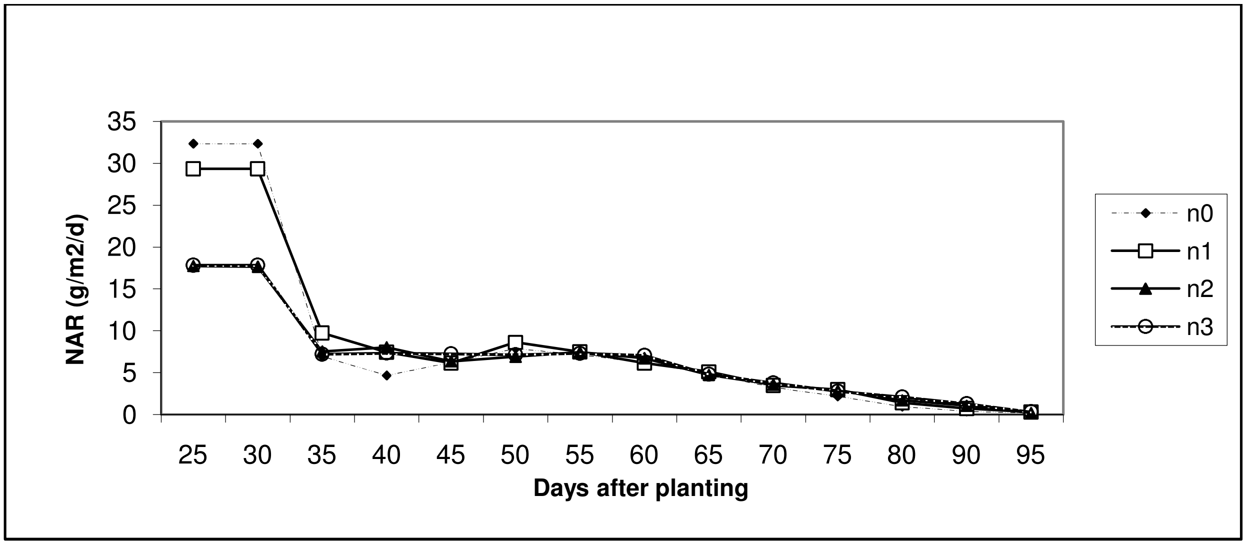

Figure 10. NAR trend in different nitrogen levels (n0, n1, n2 and n3 are application of 0, 80, 160 and 240 kg N/ha).

Conclusion

N nutrient and plant density is still one of the major parameters limiting crop yield, plant growth and productivity. Adequate supply of N to crops is fundamental to optimize crop productivity. Growth analysis is still the most simple and precise method to evaluate the contribution of different physiological processes in plant development. Hokmalipour and Hamele Darbandi (2011) indicated that physiological growth analysis is important in prdiction of yield. Understanding physiological basis of forage sorghum in different plant densities and nitrogen levels is critical for the rationale design of agricultural practices. For all plant density treatments, from 25 days after plantation until 95 days after planting, the total dry matter trend increased gradually. The highest total dry matter was observed in 95 days after plantion which was related to 400000 plants per ha and 240 KgN/ha. Study the trend of variances of crop growth rate showed that in all treatments, the crop growth rate was low in the beginning of sampling, thereafter increased considerably up to 60 days after planting with a peak in 60 days after planting, then showed a declining trend after that. In all of plant density treatments, RGR decrease during plant growth and reached to a zero at 75-85 days after planting, and it reached into negative after these days until harvesting time. In different plant nitrogen levels, RGR trends also decrase during plant growth and reached to a zero at 40-60 days after planting. The maximum LAI was obtained for 400000 plants per ha and 160 kgN/ha. Study of trend of net assimilation ratio (NAR) showed that in all treatments, the NAR was stable in the beginning of sampling, thereafter showed a declinig trend that toward zero (90-95 days after planting).

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