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## Investigation Growth Indices Analysis and Sorghum (*Sorghum bicolor* L.) Crop Production Affected Different Level of Nitrogen and Nitroxin Bio-Fertilizer

Armaghan Charkhab<sup>1</sup> and Mani Mojaddam<sup>2\*</sup>

1- Msc. Graduated, Department of Agronomy, Ahvaz branch, Islamic Azad University, Ahvaz, Iran.

2- Assistant Professor, Department of Agronomy, Ahvaz branch, Islamic Azad University, Ahvaz, Iran.

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### ABSTRACT

**BACKGROUND:** Bio-fertilizers being essential components of organic farming play vital role in maintaining long term soil fertility and sustainability.

**OBJECTIVES:** Study yield and growth indices of sorghum in response to consume chemical fertilizer and Nitroxin bio-fertilizer.

**METHODS:** This research was conducted via split plot experiment based on completely randomized block design with three replications in research field of Ahvaz Islamic Azad University. Pure nitrogen from urea source was used as the main plot in four levels (0, 50, 100, 150 kg.ha<sup>-1</sup>) and Nitroxin bio-fertilizer was used as sub plot in two levels (lack of use of bio-fertilizer and use of 1 L.ha<sup>-1</sup> Nitroxin per 200 kg seeds).

**RESULT:** According result of analysis of variance effect of different level of nitrogen and Nitroxin on seed yield, biologic yield and harvest index was significant at 1% probability level but interaction effect of treatments on harvest index was not significant. Assessment mean comparison of different levels of nitrogen fertilizer indicated that the highest seed yield (341 g.m<sup>-2</sup>), biologic yield (1218 g.m<sup>-2</sup>) and harvest index (28%) belonged to the treatment with consumption of 150 kg.ha<sup>-1</sup> nitrogen and the lowest amount of seed yield (200 g.m<sup>-2</sup>) biologic yield (1045 g.m<sup>-2</sup>) and harvest index (20%) was for non-consumption of nitrogen (control). Use 1 L.ha<sup>-1</sup> Nitroxin led to achieve highest seed yield (324 g.m<sup>-2</sup>), biologic yield (1185 g.m<sup>-2</sup>) and harvest index (27%) compare to control treatment. The highest leaf area index was obtained in the application of bio-fertilizer compared to non-consumption (4.5), and the non-use of biological fertilizer with a maximum leaf index was 3.8. Net assimilation rate in the use of biological fertilizer at 25 days after planting the equivalent of 10 gr.m<sup>-2</sup> per day started and in the 47 days after planting, it was 6.3. The non-use of biological fertilizer began at 8.1 after 25 days after planting and reached 6.1 in 47 days after planting.

**CONCLUSION:** So finally consume 150 kg.ha<sup>-1</sup> chemical nitrogen fertilizer with 1 L.ha<sup>-1</sup> Nitroxin bio-fertilizer advised for farmers.

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**KEYWORDS:** *Dry matter, Leaf area index, Nitrogen, Yield.*

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## 1. BACKGROUND

Sorghum is a widely grown cereal crop, particularly in Africa, sorghum ranks 5<sup>th</sup> in global cereal production. Seed sorghum is a dominant summer crop in Sudan; many varieties are grown under rain-fed areas and under irrigation in some central states (Ali *et al.*, 2015). Forage crops play an important role in supplying energy and protein to livestock (Eskandari *et al.*, 2009). In breeding of forage crops, increase of yield and forage quality are the main factors which play prominent role in the introduction of new varieties. Forages with good quality should have high dry matter yield, energy, digestibility and low fiber for optimal fermentation in the silo and storage. (Curran and Posch, 1999). Sorghum is the fifth most important cereal crop grown for human consumption in the world being surpassed only by rice, wheat, barley and corn. Most of sorghum grown in Asia and the African tropics is used for human food and also fed to livestock or poultry (Gul *et al.*, 2005). Sorghum production in Iran has spanned almost 120 yr. The crop has served producers and end users well, as advancements in cultivar development have produced the high-performing, well adapted, premium quality cultivars. For example, screening of seven salinity tolerant and ten salinity sensitive sorghum genotypes was reported (Chuck and Donnelly, 2014). Sorghum is a versatile crop which is grown for human consumption, animal feeds, and poultry nutrition and for some industrial products (Amal *et al.*, 2010). Grain sorghum as a staple food grain in several developing countries (Buah and Mwinkaara, 2009) is an important crop in arid and semiarid regions, because of its environmental adaptability. The productivity of grain sorghum could be increased by improving the cultural practices, such as irrigation regime, nitrogen ferti-

lizer and plant density. Sorghum is an important cereal grain due to its drought resistance and relatively low input costs. Worldwide, sorghum is ranked fifth among cereal grains in terms of quantity and importance (Rooney and Awika, 2005). Nutrient management is one of the most important factors that affect the growth and yield of maize (Verma, 2011). Fertilizer management is one of the most important factors in successful cultivation of crops affecting yield quality and quantity (Tahmasbi *et al.*, 2011). A great attention has recently directed towards the application of bio-organic farming to avoid the heavy use of agrochemicals that result in enormous environmental troubles (Abd El-Ghany, 2007). Organic manure contains higher level of relatively easily available nutrient elements, which are essentially required for plant growth. Moreover, it plays an important role to improve physical soil properties (Amal *et al.*, 2010). Many researchers investigated the nutrient value of organic manure and bio-fertilizers for crop production and indicated that it could be used successfully. There exists a large volume of literature reporting the efficiency and effectiveness of the organic fertilizer nutrient sources in maintaining soil fertility, improving crop yields and sustaining productivity and that display their increased potential when integrated with inorganic fertilizer (El-Mekser, 2004). Bio-fertilizers are more environmental friendly and in many cases, they have given the same or even better crop yields compared to mineral fertilizers (Saghir Khan *et al.*, 2007). Bio-fertilizers are being essential component of organic farming are the preparations containing live or latent cells of efficient strains of nitrogen fixing, phosphate solubilizing or cellulolytic micro organisms used for application to seed, soil or composting areas with the objec-

tive of increasing number of such micro-organisms and accelerate those microbial processes which augment the availability of nutrients that can be easily assimilated by plants. Bio-fertilizers play a very significant role in improving soil fertility by fixing atmospheric nitrogen, both, in association with plant roots and without it, solubilize insoluble soil phosphates and produces plant growth substances in the soil. They are in fact being promoted to harvest the naturally available, biological system of nutrient mobilization (Venkatashwarlu, 2008). Inoculation with *Azospirillum* and *Azotobacter* increases the absorption of K,  $\text{NO}_3^-$ ,  $\text{H}_2\text{PO}_4$ , so the root to stem ratio seems to increase. This makes the plant better deployed in the soil and access to limited resources of water and essential nutrients. Increasing the absorption of ions by inoculation can play an important role in increasing leaf growth. Also, the release of various phytohormones, such as auxin, cytokinin, gibberellin, and unknown compounds by strains of these bacteria, increase the cell proliferation and cell division, so increasing the leaf area index can be justified (Yazdani *et al.*, 2009). Jafari Haghighi and Yarmahmodi (2011) by evaluate the effects of chemical and biological fertilizers on physiological traits of corn under different irrigation regime reported to achieve high yield use biological fertilizer cannot sufficient but integrated application of fertilizers (Biological and Chemical fertilizers) became causes significant increase in yield can be advised. Hokm Alipour and Hamele Darbandi (2011) reported application of nitrogen fertilizer has positive effects on yield and physiological growth indices of maize cultivars, it can be suggested that use korduna cultivar with 180 kg N ha levels. Nouraki *et al.* (2016) reported bacteria have positive role in the produc-

tion of bio-fertilizers and hormones which play a significant role in regulating plant growth while mixing them with chemical fertilizers as a supplement the level and depth of the roots. This combination also increases the rate of water and nutrient absorbance which raise the rate of growth and photosynthesis. These combination also increase the grain yield, yield components, and biological function, it has been found that bio-fertilizers can be combined with chemical fertilizers in a complementary way to reduce the excessive amount of chemical fertilizers used to grow corn. It was shown that the mixing of biological fertilizers with chemical fertilizers could reduce the needs of chemical fertilizers up to 25% and these results are comparable to the application of 100% chemical fertilizers. Therefore, the best hybrid maize is the single cross 704 that has good yield potential when the chemical fertilizer is used at either 25% or 50% of the current application when mixed with the bio-fertilizer. Rai and Caur (1998) studied *Azotobacter* and *Azospirillum* and double-inoculation and alone inoculation effects on wheat growth and yield. Double-inoculation of *Azotobacter* and *Azospirillum* had positive effects on plant height, spike length, grain yield, biological yield and harvest index in various wheat genotypes. It is proved that hormones such as oxine, gibberline and cytokenine are synthesized by many *Azotobacter* spp (Singh *et al.*, 2004). Nitroxin is an *Azotobacter* biological fertilizer which leads to higher quality yields (Kholdi *et al.*, 2015). The Nitroxin biological fertilizer also contains nitrogen stabilizing bacteria, which is produced and supplied with the approval of the country's research institutes (Asadi-Kupal and Zadeh Laserjan, 2009). The bacteria in the Nitroxin biological fertilizer, in addition to stabiliz-

ing nitrogen of the air and balancing the absorption of macro and micronutrient elements, stimulate growth of the hormones by synthesizing and securing growth promoters such as hormones (Fulchirri and Frioni, 1994). Rahi (2013) reported that increase in Nitroxin also increased fresh and dry weights of leaf, stem, chlorophylls a, b, total carotenoids, and anthocyanin content of the plants linearly. Yield is a complex trait resulting from interaction of morphological, physiological and environmental parameters on the growth of plants. Identification of the variations of morphological and physiological traits influencing the yield of a plant in a certain environment is an essential tool for selecting and breeding of yield (Azarpour *et al.*, 2014). Increasing leaf area determines the photosynthetic capacity of the plant. The variation in leaf area affected by genotype, plant density, and climate and soil fertility will also affect performance (Nezarat and Gholami, 2008). High level of leaf area index increases mean growth rate (CGR) during plant growth period, which in the end results in increase of dry matter production (biomass) and increase of yield of product. Research results of the researchers have shown that there is a positive correlation between leaf area index and dry matter yield, so that the increase of leaf area index with increasing light absorption and thereby increasing photosynthetic capacity will increase economic performance (Sajedi and ardakani, 2007). Growth analysis is a way to assess what events occurs during plant growth. Growth analysis is a suitable method for plant response to the different environmental conditions during plant life (Tesar, 1984). Nitrogen is one of the important agronomy factors which has a significant impact on growth indices and by selecting the appropriate amount of nitrogen, balanced

complex of growth indices will be create in canopy which lead to yield improvement since the most indicators of growth are related to leaf area index in some way. Leaf area index changing through alteration in nitrogen fertilizer levels is one of the most practical ways. In every region, leaf area index which produces the maximum yield is different and it should be obtained by the local research (Azarpour *et al.*, 2014). Identification of growth physiological indices in analysis of factors affecting yield and its components has a great importance and its stability determines the dry matter production which is a criterion of yield components and in this regard leaf area index (LAI), total dry weight (TDW) and leaf dry weight (LDW) should be measured in periodic intervals during the growing season (Gardner *et al.*, 1985). The above indices plus crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), leaf area duration (LAD), leaf area rate (LAR), leaf weight rate (LWR) and specific leaf area (SLA) are indices which often use for evaluation of plant productivity capability and environmental efficiency (Anzoua *et al.*, 2010). Leaf area index (LAI) and dry matter production is the main growth factor which may directly reflect to cotton yield. Growth analysis parameters like crop growth rate (CGR) are product of LAI. Relative growth rate (RGR) measures the increase in dry matter with a given amount of assimilatory material at a given point of time (Rajput *et al.*, 2017). Sharifi *et al.*, (2014) reported that during plant growth stages RGR values are interrelated to dry matter accumulation and crop growth rate. The amount of growth and photosynthetic translocation is related to nutrients availability (Munir *et al.*, 2012). Dwyer and Tewart (1986) reported that leaf area index is major factor determining

photosynthesis and dry matter accumulation. Crop growth rate is related to leaf area index, for this reason that crop growth rate changes is depended to two parameters: namely leaf area index and net assimilation rate. Leaf area index is the component of crop growth analysis that accounts for the ability of the crop to capture light energy and is critical to understanding the function of many crop management practices. Leaf area index can have importance in many areas of agronomy and crop production through its influence on: light interception, crop growth weed control, crop-weed competition, crop water use, and soil erosion. To measure LAI, scientists generally have cut a number of plants at the soil surface, separated leaves from the other plant parts, and measured the area of individual leaves to obtain the average leaf area per plant. The product of leaf area per plant and the plant population gives the LAI. Alternatively, LAI could be measured non-destructively with this procedure if area of individual leaves was determined by some combination of leaf length and width measurements (Shirkhani and Nasrolahzadeh, 2016).

## 2. OBJECTIVES

This research is aimed to examine the changes of yield and growth indices of sorghum by using Nitroxin bio-fertilizer.

## 3. MATERIALS AND METHODS

### 3.1. Field and Treatments Information

In order to study evaluation of yield and growth indices of sorghum in response to Nitroxin bio-fertilizer, this research was carried out according split plot experiment based on completely randomized block design with three replications in the research field of Ahvaz Islamic Azad University. Pure nitrogen from urea source was used as the main plot in

four levels (0, 50, 100, 150 kg.ha<sup>-1</sup>) and Nitroxin bio-fertilizer was used as the sub plot in two levels (lack of use of bio-fertilizer and use of 1 L.ha<sup>-1</sup> Nitroxin per 200 kg seeds).

### 3.2. Farm Management

Urea and triple super phosphate were the sources of chemical fertilizers of nitrogen and phosphorus used in the experiment. Potassium fertilizer was not used due to high level of absorbable potassium. 1 liter of Nitroxin bio-fertilizer was used before planting as mixed with the seeds. The required amounts of nitrogen fertilizers were identified after the soil analysis and the needed fertilizer for each plot was calculated with regard to the plot size and the levels of studied treatments and 25% of pure nitrogen as the base fertilizer was added to the land before planting and 75% was added at 8-leaf stage. There were 8 plots in each block. The space between each sub plot from the other one was as one non-planting line and the space between every two main plots was as two non-planting lines. There were 6 planting rows in each plot and the space between the rows was 75 cm and over the rows was 12 cm. Cultivar seeds were used. The seeds were planted at the end of July as ridge and furrows at the depth of 3-4 cm. in seed mixing method, after blending the seeds they were dried in shadow and immediately planted. After sowing the seeds, the field was irrigated. During the growth stage, growing operations such as irrigation, thinning and controlling the weeds (at 4-leaf stage) were done.

### 3.3. Measured Traits

In order to determine the yield two planting lines from each plot and after the removal of marginal effect were carried to the laboratory and were placed in the oven at 75°C for 48 hours and after

ensuring that the samples were completely dry, they were weighed and finally the total yield was measured. By measuring three factors including leaf area, leaf dry weight and total body weight, the physiological parameters of growth including LAI, NAR, and CGR were obtained using the following equations. To determine the leaf area of the linear relationship  $S = K \cdot L \cdot W$  was used in which S, L and W were the leaf area, L and W respectively, the maximum length and width of each leaf and  $K = 0.75$  correction coefficient. The LAI was calculated from leaf area ratio to ground level. CGR and net assimilation rate was measured according following formula (Buttery, 1970; Enyi, 1962):

$$\text{Equ.1. CGR (gr.m}^{-2}\text{.day}^{-1}) = (W_2 - W_1) / (T_2 - T_1)$$

$W_1$  = Primary dry weight (g)

$W_2$  = Secondary dry weight (g)

$T_1$  = initial sampling time

$T_2$  = Secondary sampling time

$$\text{Equ.2. NAR (gr.m}^{-2}\text{.day}^{-1}) = \text{CGR} \times \ln(LA_2 / LA_1) / (LA_2 - LA_1)$$

CGR = Growth rate in  $\text{gr.m}^{-2}$

$LA_1$  = Initial leaf area

$LA_2$  = Secondary leaf area

### 3.4. Statistical Analysis

The data related to studied traits were analyzed with using SAS software (Ver.10) and data were compared by using Duncan test at 5% probability level. Excel software (Ver.2010) was used to draw diagrams and curves.

## 4. RESULT AND DISCUSSION

### 4.1. Seed Yield

The seed yield is a complex feature whose emergence depends on the function of the reactions of many physiological combinatorial processes, in particular the limiting components that change with the varieties. According result of analysis of variance effect of different level of nitrogen, Nitroxin and interaction effect of treatments on seed yield was significant at 1% probability level (Table 1). Mean comparison of different levels of nitrogen fertilizer indicated highest seed yield ( $341 \text{ g.m}^{-2}$ ) belonged to the treatment with consumption of  $150 \text{ kg.ha}^{-1}$  nitrogen and the lowest one ( $200 \text{ g.m}^{-2}$ ) was for non-consumption of nitrogen (control) (Table 2).

**Table 1.** ANOVA results of studied traits in response to different level of nitrogen and Nitroxin

S.O.V	df	Seed yield	Biological yield	Harvest index
Replication	2	51.73 <sup>ns</sup>	36.34 <sup>ns</sup>	21.78 <sup>ns</sup>
Nitrogen	3	248.27 <sup>**</sup>	389.63 <sup>**</sup>	68.7 <sup>**</sup>
Error I	6	48.46	44.70	19.2
Nitroxin	1	230.58 <sup>**</sup>	581.58 <sup>**</sup>	60.4 <sup>**</sup>
Nitrogen*Nitroxin	3	245.29 <sup>**</sup>	299.45 <sup>**</sup>	28.3 <sup>ns</sup>
Error II	8	54.68	50.53	22.11
CV (%)	-	9.38	12.29	9.10

<sup>ns</sup>, <sup>\*\*</sup>, <sup>\*</sup>: Mean of squares of treatments respectively non-significant, significant at 1% and 5% probability levels.

**Table 2.** Mean comparison effect of different level of nitrogen fertilizer on studied traits

Treatment	Seed yield ( $\text{g.m}^{-2}$ )	Biological yield ( $\text{g.m}^{-2}$ )	Harvest index (%)
<b>Nitrogen</b>			
Control	200 <sup>*d</sup>	1045 <sup>c</sup>	20 <sup>d</sup>
50 $\text{kg.ha}^{-1}$	231 <sup>c</sup>	1117 <sup>b</sup>	21 <sup>c</sup>
100 $\text{kg.ha}^{-1}$	304 <sup>b</sup>	1176 <sup>b</sup>	25 <sup>b</sup>
150 $\text{kg.ha}^{-1}$	341 <sup>a</sup>	1218 <sup>a</sup>	28 <sup>a</sup>

\*Similar letters in each column show non-significant difference at 5% probability level in Duncan test.

It seems like that the increase of seed yield is due to the positive effect of nitrogen and receiving light and the increase of photosynthesis, crop growth rate, leaf area index, and leaf area duration. The results are consistent with the findings of (Nawas *et al.*, 2005). In another study conducted by (Garg *et al.*, 2005) increasing nitrogen to soil increased the plant photosynthetic efficiency and ultimately increased the seed yield and growth rate. On the other hand, since the rate of light absorption by leaves and converting it into photosynthetic materials are the other factors affecting the plant growth and production, the increase of leaf area in the farm leads to the increase of light absorption and ultimately leads to the increase of seed yield. Application of inorganic fertilizers along with bio-fertilizer significantly increased maize yield (Abou El-Magd *et al.*, 2006). Manure application has also been reported to increase the N and exchangeable cation levels in the soil (Boateng *et al.*, 2006). Nitroxin biological fertilizer contains the most effective nitrogen fixation bacteria of *Azotobacter* and *Azospirillum*, which stabilizes the nitrogen, balance absorption of micronutrient and macronutrient rate needed by plant, as it causes growth and development of root and shoots of plant by synthesis and excretion of stimulants of plant growth such as types of regulating hormones such as Oxine, and also production of different amino acids and types of antibiotics, Cyanide hydrogen, Siderophore, etc, and causes increase of quality and quantity of product by protecting root such as terrestrial pathogenic agents (Cardoso and Kuyper, 2006). According result of mean comparison of different level of Nitroxin maximum seed yield ( $324 \text{ g.m}^{-2}$ ) was obtained for use  $1 \text{ L.ha}^{-1}$  Nitroxin and minimum of that ( $214 \text{ g.m}^{-2}$ ) was for control treatment (Table 3). Useful

soil bacteria, by facilitating elements uptake, atmospheric nitrogen fixation, plant hormone production such as auxin and gibberellin, increase the yield components and the seed yield, ultimately (Gary *et al.*, 2005). Hamidi *et al.* (2007) examined the effect of growth enhancer bacteria on post-mature hybrids of maize in an experiment and reported that application of such bacteria increased the seed yield. Assessment mean comparison of interaction effect of treatments revealed the highest rate of seed yield ( $349 \text{ g.m}^{-2}$ ) was noted for treatment of  $150 \text{ kg.ha}^{-1}$  nitrogen fertilizer with  $1 \text{ L.ha}^{-1}$  Nitroxin and the lowest rate ( $207 \text{ g.m}^{-2}$ ) belonged to the treatment without consumption of the nitrogen and Nitroxin bio-fertilizer (Table 4).

#### 4.2. Biologic Yield

Result of analysis of variance revealed effect of different level of nitrogen, Nitroxin and interaction effect of treatments on biologic yield was significant at 1% probability level (Table 1). Mean comparison of different level of nitrogen indicated the maximum biologic yield ( $1218 \text{ g.m}^{-2}$ ) was obtained for consumption of  $150 \text{ kg.ha}^{-1}$  nitrogen and minimum of that ( $1045 \text{ g.m}^{-2}$ ) was for control treatment (Table 2), so due to increase leaf area index and plant growth, and positive effect on foliage development and seed yield due to nitrogen application. According result of mean comparison of different level of Nitroxin maximum biologic yield ( $1185 \text{ g.m}^{-2}$ ) was obtained for use  $1 \text{ L.ha}^{-1}$  Nitroxin and minimum of that ( $1092 \text{ g.m}^{-2}$ ) was for control treatment (Table 3). Bio-fertilizer seems to increase the efficiency of nitrogen absorption and increase the number of aerial parts and consequently increase biological yield.

**Table 3.** Mean comparison effect of use or nonuse of Nitroxin on studied traits

Treatment	Seed yield (g.m <sup>-2</sup> )	Biological yield (g.m <sup>-2</sup> )	Harvest index (%)
<b>Nitroxin</b>			
Control	214 <sup>*b</sup>	1092.4 <sup>b</sup>	20 <sup>b</sup>
1 L.ha <sup>-1</sup>	324 <sup>a</sup>	1185.6 <sup>a</sup>	27 <sup>a</sup>

\*Similar letters in each column show non-significant difference at 5% probability level in Duncan test.

**Table 4.** Mean comparison interaction effect of different level of nitrogen and Nitroxin on studied traits

Nitrogen	Nitroxin	Seed yield (g.m <sup>-2</sup> )	Biological yield (g.m <sup>-2</sup> )
Control	Control	207 <sup>s</sup>	1004 <sup>*f</sup>
	1 L.ha <sup>-1</sup>	217 <sup>f</sup>	1011 <sup>e</sup>
50 kg.ha <sup>-1</sup>	Control	233 <sup>c</sup>	1074 <sup>d</sup>
	1 L.ha <sup>-1</sup>	258 <sup>d</sup>	1133 <sup>c</sup>
100 kg.ha <sup>-1</sup>	Control	275 <sup>c</sup>	1186 <sup>b</sup>
	1 L.ha <sup>-1</sup>	296 <sup>b</sup>	1234 <sup>ab</sup>
150 kg.ha <sup>-1</sup>	Control	317 <sup>b</sup>	1204 <sup>b</sup>
	1 L.ha <sup>-1</sup>	349 <sup>a</sup>	1266 <sup>a</sup>

\*Similar letters in each column show non-significant difference at 5% probability level in Duncan test.

Hamidi *et al.* (2007) also investigated the effect of plant growth stimulating bacteria on the yield of corn, and concluded that growth promoters significantly increased the biological yield of corn, which was consistent with the results of this research. Evaluation mean comparison of interaction effect of treatments revealed the highest rate of biologic yield (1266 g.m<sup>-2</sup>) was noted for 150 kg.ha<sup>-1</sup> nitrogen fertilizer with 1 L.ha<sup>-1</sup> Nitroxin and the lowest one (1004 g.m<sup>-2</sup>) belonged to treatment without consumption of nitrogen and Nitroxin bio fertilizer (Table 4).

#### 4.3. Harvest Index

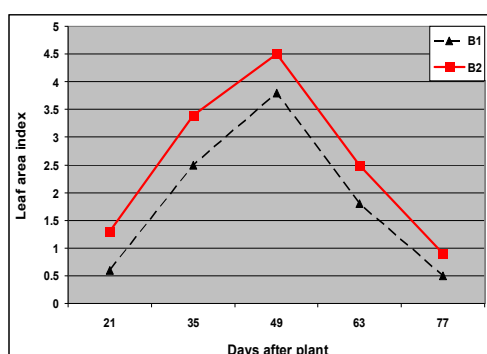
According result of analysis of variance effect of different level of nitrogen and Nitroxin on harvest index was significant at 1% probability level but interaction effect of treatments was not significant (Table 1). Mean comparison of different levels of nitrogen fertilizer indicated that the highest harvest index (28%) belonged to the treatment with consumption of 150 kg.ha<sup>-1</sup> nitrogen

and the lowest one (20%) belonged to the treatment without consumption of nitrogen (control) (Table 2). The variability of the harvest index in the plants depends on the difference in the production of the assimilates during the seed filling and re-transplantation of the assimilates before the pollination of each genotype and the strength of the reservoir (Nour mohammadi *et al.*, 2001). The results show that the increase in nitrogen increases the biological yield and, in due proportion, increases the distribution of photosynthetic material to the reproductive organs in the plant. Also, use or nonuse of Nitroxin had the highest and lowest harvest index with average of 27 and 20%, respectively (Table 3). Han and Lee (2006) attributed the increase in corn harvest index in bio-fertilizer treatment to better absorb nutrients. Because the plant with better absorption of nutrients and increasing leaf area index can use better solar radiation and send more photosynthetic materials to seed and thus increase dry matter.

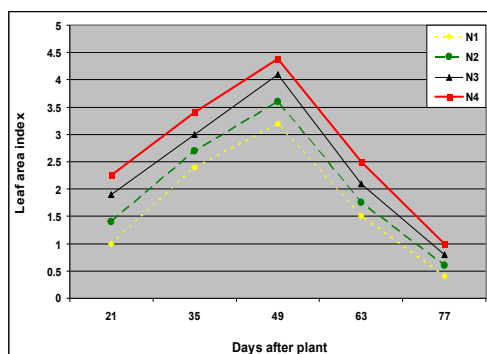


#### 4.4. Leaf area index (LAI)

In this study, leaf area index (LAI) changes were evaluated based on the effect of Nitroxin and pure nitrogen fertilizer. Fig. 1 and 2 shows variation of leaf area index from the beginning of the growing season to the last stage of sampling under the influence of Nitroxin bio fertilizer and pure nitrogen fertilizer, the LAI at the beginning of the season growth was an increasing trend and continued up to 40-50 days after the planting, after declining contraction.



**Fig. 1.** Effect of nonuse and use of Nitroxin biofertilizer (B<sub>1</sub> and B<sub>2</sub> respectively) on leaf area index.



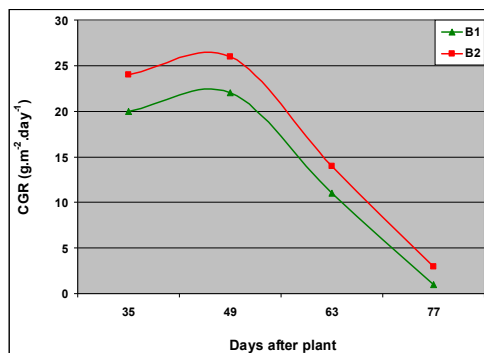
**Fig. 2.** Effect of different level of nitrogen fertilizer (N<sub>1</sub>:0, N<sub>2</sub>:50, N<sub>3</sub>:100 and N<sub>4</sub>: 150 kg N ha) on leaf index.

This trend is also consistent with the results of other researchers (Raker, 2004). The highest leaf area index was obtained in the treatment of biological fertilizer application (4.5), and the non-use of biological fertilizer with a maxi-

imum leaf index was 3.8 (Fig. 1). The results showed that the effect of biological fertilizers on the increase of leaf area index was significant. This is due to the fact that Azospirillum and Azotobacter bacteria, by providing nitrogen, improve the vegetative growth and leaf development, followed by the increase of leaf area index. Considering that the main factor influencing the growth and production of arable crops is the absorption of light by leaves and its transformation into photosynthetic materials, increasing the amount of leaf area in the field increases the amount of light absorption that leads to increased yield. About the different levels of fertilizer, leaf area index in the control treatment, 50 kg, 100 kg, 150 kg of pure nitrogen fertilizer was respectively 3.1, 3.5, 3.8, 4 (Fig. 2).

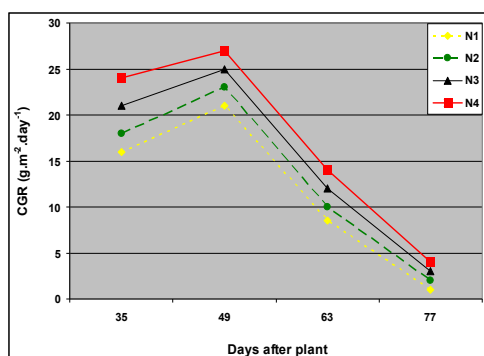
#### 4.5. Crop Growth Rate (CGR)

Growth rate of crop growth in early stages of growth due to sufficient vegetation and increased leaf area, resulting in better sunlight production, increased dry matter production per unit area, and consequently the growth rate of crop growth has been increasing. The amount of product growth rate has peaked at the earliest stages of seed filling. At this time, the plant had the maximum leaf area index. As the plant reaches the ultimate height of growth due to shadowing of the upper limbs on the shrubs, decreasing the plant's photosynthetic capacity, aging and leaf loss, the growth rate of the crop has been greatly reduced. According to the figure 3, in the application of biological fertilizer, the maximum crop growth rate was obtained with a numerical value of 25 gr.m<sup>-2</sup>.day<sup>-1</sup> in the 46 days after planting, which compared to the non-consumption of 21 g.m<sup>-2</sup>.day<sup>-1</sup>, which was still maximal growth at 46 days after planting (Fig. 3).



**Fig. 3.** Effect of nonuse and use of Nitroxin biofertilizer (B<sub>1</sub> and B<sub>2</sub> respectively) on Crop Growth Rate (CGR)

The reason for this can be explained by the fact that biological fertilizers with the ability to stabilize nitrogen, expand the root surface, help to optimally absorb water and nutrients, and produce growth hormones and some vitamins, plant growth rate amplifies; strengthens; intensifies. Comparing the rate of growth of the product of treatments with different amounts of applied fertilizer, the growth rate of the product in the treatment of 150 kg of chemical fertilizer with a value of 28 gr.m<sup>-2</sup>.day<sup>-1</sup> which was obtained 46 days after planting which was superior to other treatments. The next treatment was the application of 100% chemical fertilizer, which was obtained again 46 days after planting and at 27 gr.m<sup>-2</sup>.day<sup>-1</sup> (Fig. 4).

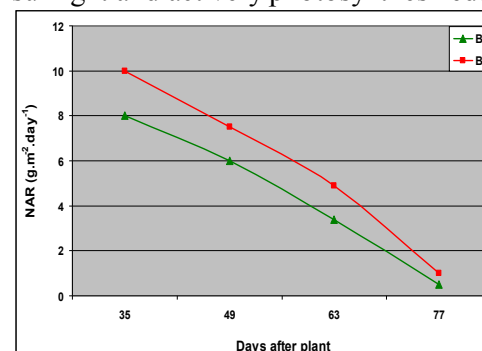


**Fig. 4.** Effect of different levels of nitrogen fertilizer (N<sub>1</sub>:0, N<sub>2</sub>:50, N<sub>3</sub>:100 and N<sub>4</sub>: 150 kg N ha) on Crop Growth Rate.

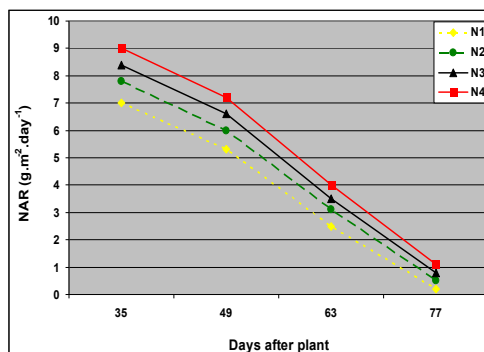
Wu *et al.* (2005) also reported that inoculation of corn grains with biological fertilizers increased the growth rate of crops. The researchers reasoned this by increasing the availability of nutrients and improving the absorption of nutrients by the plant. Hokm Alipour and Hamele Darbandi (2011) reported negative values of crop growth rate and relative growth rate are due to loss of leaves at the end of the growing season. So with increasing nitrogen levels at all of the corn cultivars plant height was significantly increased. Clarke and Simpson (1978) stated that simultaneously the maximum growth rate of the product was due to the increase in the durability of photosynthetic organs, which increased in the presence of biological fertilizers. Many researchers have stated that biological fertilizers alone cannot provide the total nitrogen needed by the plant, and the positive effects of biological fertilizers on the availability of other elements such as phosphorus through increased solubility and absorption and the production of various growth-promoting hormones (Vessy, 2003).

#### 4.6. Net Assimilation Rate (NAR)

In Fig. 5 and 6, at early growth of plants, the net absorption rate was maximal in net due to the fact that the whole surface of the leaves was exposed to sunlight and actively photosynthesized.



**Fig. 5.** Effect of nonuse and use of Nitroxin biofertilizer (B<sub>1</sub> and B<sub>2</sub> respectively) on Net Assimilation Rate (NAR).

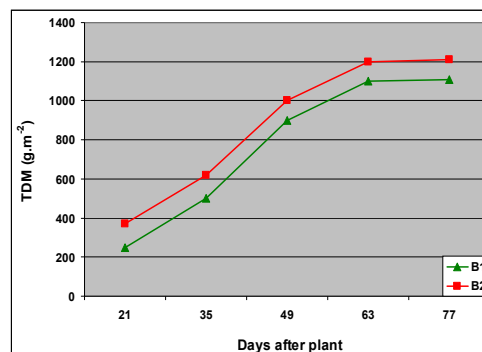


**Fig. 6.** Effect of different levels of nitrogen fertilizer ( $N_1$ :0,  $N_2$ :50,  $N_3$ :100 and  $N_4$ : 150 kg N ha) on Net Assimilation Rate (NAR).

So the trend is declining over time. Main reasons for decrease in rate of net absorption at end of growth period is shading on same time, increasing average age of leaves and consequently, decreasing photosynthetic efficiency of leaves. The rate of pure assimilation in use of biological fertilizer in the 25 days after planting began at  $10 \text{ gr.m}^{-2}$  and in 47 days after planting was 6.3, and to avoid using biological fertilizer within 25 days after planting from 8.1 Beginning and in the 47 days after planting it has reached 6.1 (Fig. 5). Pure absorption rate in nitrogen application due to the lack of application of any food-stuffs. The slope of curve was decreased due to loss of leaves and lack of material from plant and rapid entry of plants in this treatment into reproductive phase. Pure absorption rate at end of growth season it is more negative than information obtained from other growth curves. In treatments 150 kg fertilizer, due to presence of food stuffs less than control treatment, leaf loss was less and curvature drop was lower (Fig. 6).

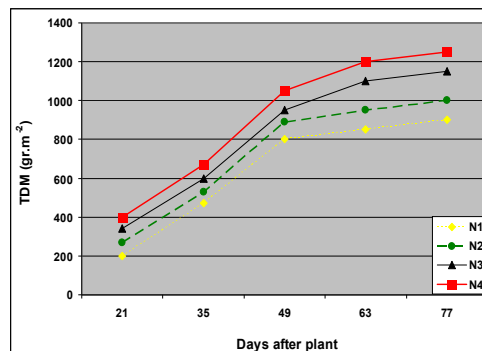
#### 4.7. Total Dry Matter (TDM)

As shown in Fig. 7 and 8, TDM changes were increasing at the beginning of the growth, and this trend continued until 63 to 70 days after planting, followed by a downward trend it took itself.



**Fig. 7.** Effect of nonuse and use of Nitroxin biofertilizer ( $B_1$  and  $B_2$  respectively) on Total Dry Matter (TDM).

High performance is conditioned by the production of high dry matter per unit area. The results of this study showed that the dry matter accumulation process varies during different stages of growth, but the three major stages of growth can be distinguished in the Fig. 7 and 8. The first stage, the slow growth stage, which is not very much produced when the plant is still growing, so the production of dry matter is low. The second stage is a rapid growth stage due to the photosynthesis of leaves and materialization, the dry weight of the plant increases. The third stage, at this stage, simultaneously with the transfer of materials from organs to seeds, the accumulation of dry matter in the plant was fixed due to shading, aging and inadequate photosynthesis and material formation due to leaf loss.



**Fig. 8.** Effect of different levels of nitrogen fertilizer ( $N_1$ :0,  $N_2$ :50,  $N_3$ :100 and  $N_4$ : 150 kg N ha) on Total Dry Matter (TDM).

In Fig. 7, Nitroxin administration was superior to non-consumption. In Fig. 8, it is also shown effect of 150 kg.ha<sup>-1</sup> fertilizer chemical fertilizer was higher than other fertilizer levels and in comparison with control treatment.

## 5. CONCLUSION

Maximum seed and biological yield belonged to treatment with consumption of 150 kg.ha<sup>-1</sup> chemical nitrogen fertilizer and also to the treatment with consumption 1 L.ha<sup>-1</sup> Nitroxin bio-fertilizer. The highest amount of LAI was obtained in the application of bio-fertilizer treatments compared to the non-consumption (4.5), and the non-use of biological fertilizer with a maximum LAI was 3.8. NAR in the use of biological fertilizer at 25 days after planting the equivalent of 10 gr.m<sup>-2</sup>.day<sup>-1</sup> started and in the 47 days after planting, it was 6.3. Non-use of biological fertilizer began at 8.1 after 25 days after planting and reached 6.1 in 47 days after planting. Finally use 150 kg.ha<sup>-1</sup> chemical nitrogen fertilizer with 1 L.ha<sup>-1</sup> Nitroxin bio-fertilizer advised for farmers.

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## FOOTNOTES

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