Journal of Crop Nutrition Science
ISSN: 2423-7353 (Print) 2322-3227 (Online)
Vol. 1, No. 1, 2015
http://JCNS.iauahvaz.ac.ir
OPEN ACCESS

Effect of Different Levels of Nitrogen and Planting Patterns on Dry Matter Production and Growth Physiological Indices in Intercropping Maize and Sunflower

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RESEARCH ARTICLE

ARTICLE INFO.
Received Date: *28 Oct. 2014*
Received in revised form: *20 Dec. 2014*
Accepted Date: *9 Feb. 2015*
Available online: *1 Apr. 2015*

To Cite This Article: Seyed Nader Mosavian, Seyed Alireza Seyed Mohammadi. Effect of Different Levels of Nitrogen and Planting Patterns on Dry Matter Production and Growth Physiological Indices in Intercropping Maize and Sunflower. ***J. Crop. Nut. Sci., 1(1):*** *15-26, 2015.*

ABSTRACT

This research aimed at investigating the effect of different levels of nitrogen and planting patterns on dry matter production and growth physiological indices in intercropping maize and sunflower. To do this a split plot experiment carried out based randomized complete block design with three replications in research field of Shushtar Islamic Azad University. The main plot included three levels of nitrogen as N_1=50, N_2=100, and N_3=150 kg.ha^{-1} nitrogen and the sub plot included two crops monoculture (S_1=Sunflower, S_5=Maize) and three planting patterns (S_2=25% Maize + 75% Sunflower, S_3= 50% Maize + 50% Sunflower, S_4= 75% Maize + 25% Sunflower). The mixture was formed based on replacement. Result revealed that the increase of nitrogen level up to 150 kg.ha^{-1} significantly increased plant height and total fresh weight of maize and sunflower. Planting pattern influenced maize plant height and total fresh weight of maize and sunflower. The highest TDM, height, and total fresh weight of maize and LAI and total fresh weight of sunflower belonged to the second planting pattern. Result also showed that CGR, RGR, and NAR in each plant followed the general pattern of these indices and the best status was achieved at the level of 150 kg.ha^{-1} nitrogen. The highest rate of LER by 1.16 belonged to N_3S_2. That is, the intercropping yield in this case increased 16% compared with pure cultivation.

Keywords: *Fertilizer, Intercropping, Land equivalent ratio (LER).*

INTRODUCTION

Intercropping is very common in a large area of developed and developing countries in tropical areas (Baumann *et al*., 2002). Intercropping means planting more than one plant in a piece of land in a farming year so that one plant spends most of its growth period near another plant. Of course, it is not necessary to the sowing or harvest the plants simultaneously, but a plant can be sowed and harvested concurrently with or after the first plant (Dua *et al*., 2005).

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Intercropping is defined as the simultaneous growth of two or more species, grown in the same area where they share the use of resources during all or part of their growing season Small farmers are facing restrictions due to limited land and low yield of crops. Preliminary research has shown that a possible way to increase yield in fields is intercropping (Saudy and Elmetwally, 2009). Multi-cropping system is one of the effective components of sustainable agriculture. Today, multi-cropping system is highly focused by ecologists due to high diversity and biological stability (Daniel *et al*., 2001). With regard to different climatic conditions in our country, research in the field of multi-cropping systems is particularly important. Maize and sunflowers are the plants that have high yield potential in Khuzestan weather conditions. The usefulness of intercropping these two plants is reported in some researches (Shakarami and Rafiee, 2009). Research shows that biological superiority of intercropping is due to more complete use of growth resources. Intercropping components might be different in terms of the use of growth resources (Ullah *et al*., 2007). When they are intercropped, crops use light, water, and nutrients more effectively than the time when they are planted separately. Moreover, the weeds completion will lessen due to the combination of plant species that occupy two or more ecological places in the field (Zhang and Li, 2003). Biological superiority of intercropping to pure cultivation occurs when inter specific competition for sources of growth is less than intra specific competition (Weil Ray and Macfaden, 1991). In an experiment conducted by Echarte *et al*. (2011), the results showed that intercropping maize and sunflower had no advantage over the yield of pure cultivation of any of them. Moreover, the increase of yield of one of the crops in each one of the two treatments could not exactly compensate for the reduction of the yield of another crop. In a research conducted on nitrogen in intercropping sunflower and maize in Australia, Massingname *et al*. (2005) that nitrogen of two species had a significant effect on biomass about their interactive effect was not significant. Maize biomass was more than sunflower biomass. In both crops, dry matter production increased by the use of 50 $kg.ha^{-1}$ nitrogen. It seems like that with regard to the importance of tendency towards sustainable agricultural system and high importance of maize and sunflower in supplying human and livestock food, investigating the possibility of intercropping maize and sunflower and the effect of management factors such as nitrogen fertilizer are particularly important. Nitrogen as a macronutrient and due to its tasks in plant processes increases the yield (Khan *et al*., 1999). Duli Zhao *et al*. (2005) showed in an experiment that different levels of nitrogen increased dry matter yield in forage sorghum. Mohammad Abadi *et al.* (2012) reported that the highest yield of dry and fresh forage of fenugreek belonged to chemical fertilizer treatment. In general, the role of nitrogen in feeding forage plants, both in terms of reaching maximum yield and qualitative features such as the rate of forage protein, is particularly important. Aydin and Uzun (2005) and Sharifi Ashourabadi (2002) reported that nitrogen fertilizers would increase yield and crude protein. In this research, intercropping maize and sunflower at different levels of nitrogen was examined and effects of nitrogen on yield and yield components and growth physiological indices and also land equivalent ratio were studied in monoculture and intercropping with different planting patterns.

MATERIALS AND METHODS

Field and Treatment Information's

This research was conducted in (2011-2012) in the Research Field of Islamic Azad University of Shushtar (Khuzestan province, Iran). The experiment was carried out as a split plot based randomized complete block design with three replications. The main factor included three levels of nitrogen as 50 (N_1), 100 (N_2), and 150 kg.ha^{-1} (N_3) pure nitrogen from the urea source which were consumed in three stages (one-third during the planting, one-third during 3-5 leaf stage, and one-third during the emergence of maize inflorescence (tassel). Different planting ratios of maize and sunflower were placed in sub plots. Based on the rate of planted rows of each crop, the ratios included 5 planting levels as 100% pure Sunflower (S_1), 75% maize + 25% sunflower (S_2), 50% maize + 50% sunflower (S_3), 25% maize + 75% sunflower (S_4), and 100% maize (S_5). In order to form the combinations, replacement series technique was used in this research (Blackman, 1919). Before, the experiment, the compound samples were taken from seven zigzag points of the experiment site at the depth of 0-30 cm. The results are shown in table (1).

Table 1. Soil characteristics of the experimental field

Soil depth (cm)	Soil Texture	Ec (ds.m^{-1})	pH	Organic Matter (%)	Nutrients		
					Total nitrogen (%)	Phosphorus (ppm)	Potassium (ppm)
0-30	Loam-clay	4.2	7.6	0.1	0.06	12.5	130

According to the research recommendations, 75000 plants per hectare were used for both plants equally (Ghosh *et al*., 2009). Each sub plot consisted of six rows as long as 6 m with the distance of 0.75 m. Four middle rows were considered for calculating ultimate yield. The number of rows in maize and sunflower was determined based on intercropping ratio in four middle rows, so that in 50:50 intercropping ratio one row of maize and one row of sunflower were considered successively (two rows of maize and two rows of sunflower totally). In 25:75 intercropping ratio one row was allocated to row and three rows were allocated to sunflower and in 00:100 ratio, four rows were allocated to sunflower.

Crops Management

In order to remove marginal effect two side rows were set according to the type of plot mixture and the row before it that was maize or sunflower. Irrigation was done based on the requirement and via siphon. In order to prevent the possible combination of adjacent fertilizing treatments and leaching, the distance between sub plots, main plots, and blocks was 1.5 m (two rows), 2.25 (three rows), and 2 m, respectively. During the land preparation, 100 kg.ha^{-1} phosphorus and 100 kg.ha^{-1} potassium from ammonium phosphate and potassium sulfate sources were added to the soil before planting. The studied cultivars in this experiment included relatively post-matured maize hybrid 704 with growth period of 120 days and relatively post-matured sunflower record (Hashemi Dezfuli *et al*., 2000).

Traits measure

Moreover, in order to evaluate intercropping land equivalent ratio and replacement series technique were used. In order to calculate land equivalent ratio the following equation was used (FAO, 1985):

Formula 1. Land Equivalent Ratio

$$LER = \frac{Yield\ of\ intercrop\ A}{Yield\ of\ pure\ stand} + \frac{Yield\ of\ intercrop\ B}{Yield\ of\ pure\ stand}$$

If LER=1, intercropping is not superior to monoculture. If LER>1, intercropping is superior to monoculture. If LER<1, intercropping has a lower yield than monoculture system. In replacement series technique, a certain proportion of the first plant is removed and the equal amount of the second plant replaces it. In this method, it is necessary to have the same density. In order to determine growth equations 4 stages of sampling was done at certain intervals, so that about 40 days after planting and then once every 20 days, 0.5 m of each line (0.4 m^2) was harvested after removing the margin. 6 lines in maize monoculture plots and 6 lines in sunflower monoculture plots were harvested. In each sampling stage, after harvesting and determining fresh weight, two samples of the crops in the harvested area were selected to measure their leaf area, dry weight, and fresh weight. Then, the samples were carried to the laboratory and their leaf area was determined using leaf area measurement device. The sample considered for measuring dry weight was put in the oven at 75℃ for 48 hours to dry and then was measured. Dry weight and leaf area were used to calculate plant growth equations in growing degree days (GDD). In the final harvest stage after measuring the fresh weight of plants in total harvested area, two samples were selected to determine dry weight and leaf area. In estimating growth equations as the use of the number of days to each main stage of growth is not very suitable for comparing various plants at different places due to different environmental conditions, in order to overcome the defect and to achieve stable indices for estimating plant growth and determining physiological stages time the heat index of growing degree days (GDD) was used instead of time calendar. In order to express plant growth and development model based on heat accumulation, at first temperature of growth day for each day was calculated and then for all plant growth days in one stage.

Formula 2. Growing Degree Days: $GDD = [(T_{max}+T_{min})/2]-T_B$

In this formula, T_{max}= maximum daily temperature, T_{min}= minimum daily temperature and T_b= base temperature.

Since plant growth stops outside two thermal limits of growth, base temperature is considered to the extent that the plant won't grow in a lower temperature. When maximum daily temperature is more than the plant desired temperature, the desired temperature is used and when minimum daily temperature is less than base temperature, base temperature is used instead of it (Amini *et al*., 2013). In these calculations, according to studied sources, the temperatures below base temperature for maize and sunflower, i.e. 10℃, were considered to be equal to 10℃ and the ones above 30℃ were considered to be equal to 30℃.

Statistical analysis

For analyzing the data and drawing the Figures, SAS software (Ver.8) and Excel software were used respectively. Means were compared using Duncan's multi range test at 5% probability level.

RESULTS AND DISCUSSION

The ANOVA results of maize indicate that effect of nitrogen on fresh weight at probability level of 0.01 and on plant height at probability level of 0.05 is significant, but it has no effect on number of leaves per plant and the number of nodes per plant (Table 2). Since nitrogen levels changed similarly in this experiment, Nitrogen SS was separated to linear and quadratic components using orthogonal polynomial coefficients. Calculated (F) shows linear component in both plant height and total fresh weight of maize is significant at 0.01 probability level and there is a significant linear relationship between increase of these two traits and the increase of nitrogen. Quadratic effect on analysis of variance of these two traits is significant. So to linear relationship, there is no quadratic relationship between two traits and nitrogen level. Increase of these two traits for each level of nitrogen is gradual and steady.

Table 2. The analysis of variance measured traits (Number of leaves per plant, plant height, total fresh weight, and number of nodes per plant in maize)

S.O.V	df	Number of leaves per plant	Number of leaves per plant	Total fresh weight	Number of nodes per plant
Replication	2	0.41^{ns}	2.17^{ns}	2.93*	0.52^{ns}
Nitrogen	2	2.16^{ns}	4.44*	4.59**	0.46^{ns}
Linear	1	1.12	13.23**	14.23**	0.22
Quadratic	1	1.04	1.31	2.23	0.24
Error a	4	1.56	2.11	0.23	0.65
planting pattern	4	0.52^{ns}	3.70*	2.20*	0.46^{ns}
Nitrogen * Planting pattern	8	0.09^{ns}	0.48^{ns}	0.12^{ns}	0.11^{ns}
Error b	24	1.89	2.98	0.65	0.81

$^{n.s}$,*, ** = non significant, significant at 5% and 1% probability levels, respectively.

Means Comparison showed that highest plant height of maize belonged to treatment with application of 150 kg.ha^{-1} nitrogen which was significantly different from treatments with application of 50 and 100 kg.ha^{-1} nitrogen. So, increase of nitrogen level from 50 to 150 kg.ha^{-1} increased plant height in maize. The highest and lowest plant height in maize at different planting patterns belonged to S_2 and S_4 respectively and difference between the two treatments was significant (Fig. 1).

There was no significant difference between S_2 and S_5 planting patterns (Table 2). In sunflower, difference of plant height for different planting patterns was insignificant but in levels of nitrogen was significant at 5% probability level. Interactive effect of two treatments was insignificant (Table 2). Mean comparison results of plant height in sunflower for levels of nitrogen showed that highest and lowest plant height belonged to nitrogen levels of 150 and 50 kg.ha^{-1}, respectively (Fig. 2).

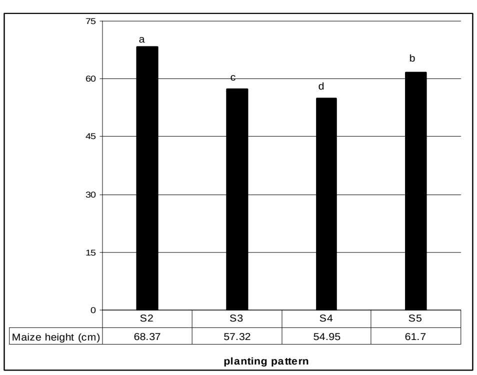

Fig. 1. Mean comparison of maize height at different planting patterns via Duncan's method (p<0.05).

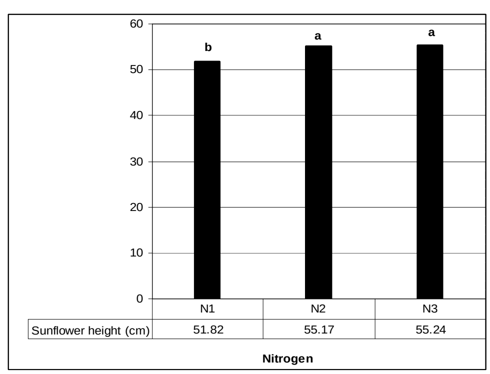

Fig. 2. Mean comparison of sunflower height at different levels of nitrogen via Duncan's method (p<0.05).

Mean comparison results of maize fresh weight showed that highest total fresh weight in maize belonged to application of 150 kg.ha^{-1} nitrogen which was significantly different from the treatment with application of 50 kg.ha^{-1} nitrogen, but was not significantly different from the treatment with application of 100 kg.ha^{-1} nitrogen (Fig. 3).

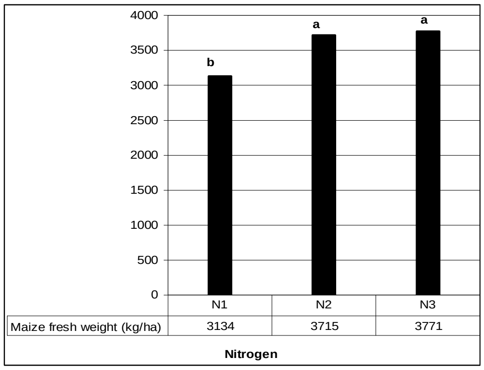

Fig. 3. Mean comparison of maize fresh weight at different levels of nitrogen via Duncan's method ($p<0.05$).

Highest total fresh weight in maize belonged to S_2 and S_5 planting patterns and lowest total fresh weight belonged to S_4 planting pattern (Fig. 4). There was insignificant difference between S_2 and S_5 planting pattern (Table 3).

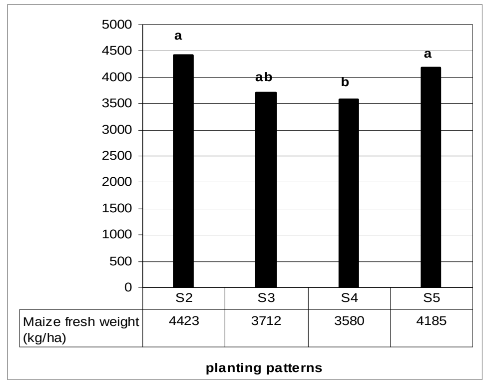

Fig. 4. Mean comparison of maize fresh weight at different planting patterns via Duncan's method ($p<0.05$).

The ANOVA results of total fresh weight in Sunflower shows that the effect of nitrogen on total fresh weight is significant at 0.05% probability level (Table 3). The highest total fresh weight in sunflower belongs to the treatment with application of 150 kg.ha^{-1} nitrogen which is significantly different from the treatment with application of 50 kg.ha^{-1} nitrogen (Fig. 5). Effect of planting pattern on total fresh weight in sunflower is significant. There is a significant difference between planting patterns at 5% probability level in terms of total fresh weight of sunflower (Table 3).

Table 3. The analysis of variance measured traits (Number of leaves per plant, plant height, total fresh weight, and number of nodes per plant in sunflower)

S.O.V	df	Number of leaves per plant	Plant height	Total fresh weight	Number of nodes per plant
Replication	2	3.01*	0.66^{ns}	2.02^{ns}	1.82^{ns}
Nitrogen	2	2.44^{ns}	4.1*	2.55*	1.77^{ns}
Linear	1	1.11	10.21*	16.28**	1.07
Quadratic	1	1.33	1.24	1.01	0.7
Error a	4	1.28	2.34	**0.77**	0.63
planting pattern	4	0.55^{ns}	0.1^{ns}	2.39*	0.04^{ns}
Nitrogen * Planting pattern	8	0.19^{ns}	0.04^{ns}	0.25^{ns}	0.05^{ns}
Error b	24	0.55	0.7	0.25	0.89

$^{n.s}$,*, ** = non significant, significant at 5% and 1% probability levels, respectively.

The highest total fresh weight in sunflower belongs to S_2 and S_1 planting patterns and the lowest total fresh weight belongs to S_4 planting pattern (Fig. 6). However, there is no significant difference between planting patterns of S_1 and S_3 (Table 3). That is, as the level of nitrogen increases, the yield and plant height of sunflower increase linearly (Table 3).

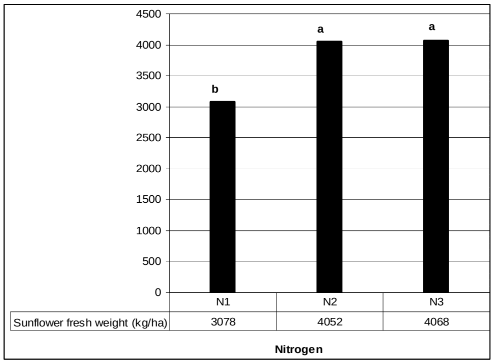

Fig. 5. Mean comparison of sunflower fresh weight at different levels of nitrogen via Duncan's method ($p<0.05$).

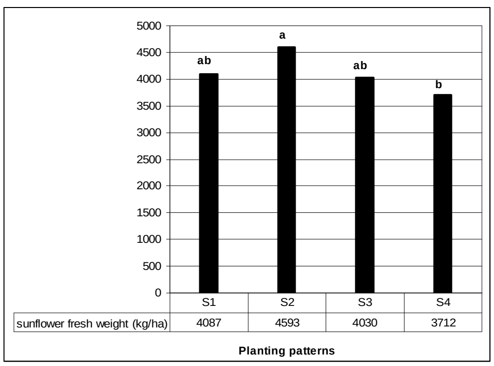

Fig. 6. Mean comparison of sunflower fresh weight at different planting patterns via Duncan's method ($p<0.05$).

In order to evaluate intercropping, land equivalent ratio (LER) was used which had formerly been applied by many researchers such as Weil Ray and Macfaden, (1991) and Hashemi Dezfuli *et al*.(2000). Value of calculated LER indicates that lowest rate of LER belongs to the treatment with application of 50 kg.ha^{-1} nitrogen and S_4 pattern. As the level of nitrogen increases, the rate of LER increases too and reaches its maximum value, i.e. 1.6 in the treatment with application of 150 kg.ha^{-1} nitrogen and S_2 planting pattern. In this case, intercropping yield is 16% more than monoculture yield (Table 4). The increase of LER due to the increase of nitrogen level has been observed in experiments conducted by Chui (1988) and Chowdhury and Rosario (1992).

Growth Indices Analysis

Plant growth is a series of special biological and physiological processes that have interactive effects on each other and are affected by environmental factors. Growth indices identification and assessment are very important in analyzing the factors influencing the yield and yield components and its stability determines the amount of dry matter production, and total dry matter production is a measure of the yield potential (Gabrielle *et al.,* 1998). Methods that are used to determine growth components of crop are introduced as the rate of growth indices. Growth analysis is very important in quantitative analysis of plant growth and development and production and its importance has been confirmed by Blackman (1919). The ANOVA results indicate that the effect of nitrogen on maize dry matter and sunflowers leaf area index is significant at 5% probability level (Table 5). The effect of planting pattern on maize dry matter and sunflower LAI is significant at 5% probability level (Table 5). Nitrogen SS separation into linear, quadratic and tertiary components shows that linear component is significant for dry matter production of maize at 5% probability level. That is, as the level of nitrogen increases, the dry matter accumulation increases linearly. Fig. (7) displays dry matter accumulation in maize at different levels of nitrogen. It indicates that highest dry matter production belongs to treatment with application of 150 kg.ha^{-1} nitrogen and lowest dry matter production belongs to treatment with application of 50 kg.ha^{-1} nitrogen. Total dry matter production can be a measure of yield potential (Fig.7).

Table 4. Calculating land equivalent ration (LER) in relation to produced dry matter

Mixed arrangement	Levels of nitrogen			LER mean at different planting pattern
	N_1	N_2	N_3	
S_2	1.03	1.09	1.16	1.09
S_3	0.93	1.02	1.11	1.02
S_4	0.79	1.01	1.06	0.95
LER mean at different levels of nitrogen	0.91	1.04	1.11	

Table 5. The analysis of variance of dry matter and leaf area index in sunflower and maize

S.O.V	df	Maize		Sunflower	
		TDM	LAI	TDM	LAI
Replication	2	3.80*	1.1^{ns}	0.85^{ns}	2.17^{ns}
Nitrogen	2	3.07*	1.22^{ns}	0.41^{ns}	4.44*
Linear	1	7.31*	1.11	0.21	12.36*
Quadratic	1	2.20*	0.11	0.2	2.01*
Error a	4	2.12	1.11	6.23	2.12
planting pattern	4	3.55*	0.34^{ns}	0.34^{ns}	3.07*
Nitrogen * Planting pattern	8	0.65^{ns}	0.27^{ns}	0.13^{ns}	0.13^{ns}
Error b	24	2.23	1.26	7.12	3.02

n.s,*, ** = non significant, significant at 5% and 1% probability levels, respectively.

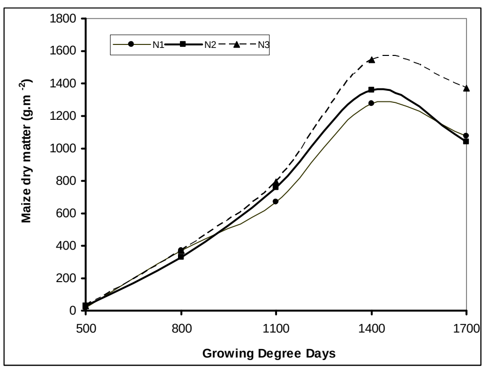

Fig. 7. Maize dry matter production at different levels of nitrogen.

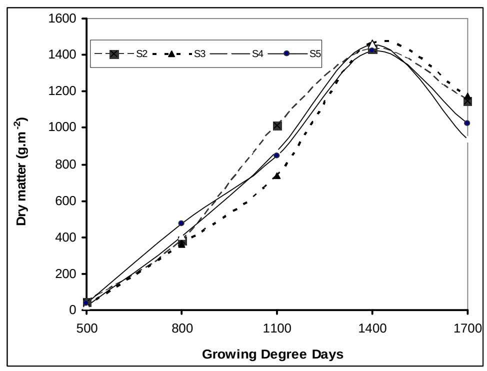

Fig. 8. Maize dry matter production at different planting patterns.

According to Fig (7) increasing trend of dry matter continues until 1400 growing degree days after planting and then nearly gets stable and after 1400 growing degree days it has a descending trend. Since reduction of dry matter accumulation is similar in all three levels of nitrogen and begins at about 1500 growing degree says, it indicates that level of consumed nitrogen at beginning of leaves loss and assimilates remobilization and ultimate during maturity stage has not been very effective. Fig. (8) show maize dry matter at different planting pattern and indicates highest rate of this trait belongs to S_2 treatment.

The ANOVA results of leaf area index in both plants indicate that in sunflower the effect of nitrogen treatment on leaf area index is significant at 5% probability level and the effect of planting pattern on leaf area index in sunflower and total dry matter production in maize is significant at 5% probability level (Table 5). In sunflower, nitrogen SS separation into linear, quadratic and tertiary effects shows that linear regression is significant at 5% probability level. That is, as the level of nitrogen increases, the leaf area index increases linearly (Table 5). Fig. (9) shows that leaf area index in sunflower increases until about 1400 growing degree days after planting, then as the leaves begin to get yellow and fall it decreases. The highest LAI belongs to the treatment with application of 150 $kg.ha^{-1}$ nitrogen.

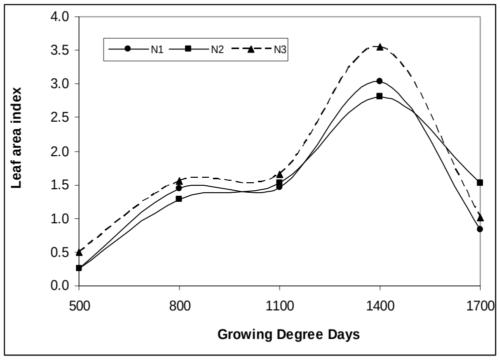

Fig. 9. Sunflower leaf area index at different levels of nitrogen.

LAI changes trend in the diagrams is exactly consistent with changes trend of dry matter production and indicates that high LAI at the level of 150 $kg.ha^{-1}$ nitrogen increases dry matter production. Figures (10) and (11) display crop growth rate (CGR) at different levels of nitrogen. According to the diagrams, growth trend in each crop is similar. The increasing trend of CGR continues until 1100 growing degree days, and then as leaf area index decreases, crop growth rate has a decreasing trend until its becomes zero in about 1300 growing degree days and after that it gets negative. This means that the rate of dry matter production due to respiration or photosynthesis in this time is less than the rate of dry matter that the plant loses due to respiration or loss of some organs such as the leaves. According to the diagrams the highest CGR belongs to the treatment with application of 150 $kg.ha^{-1}$ nitrogen which is about 2.5 $g.m^{-2}$ per growing degree days for maize and about 2.83 $g.m^{-2}$ per growing degree days for sunflower and the lowest CGR belongs to the treatment with application of 50 $kg.ha^{-1}$ nitrogen (Fig.10, 11).

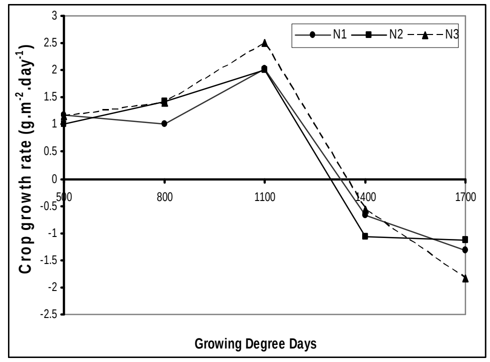

Fig. 10. Crop growth rate (CGR) of maize at different levels of nitrogen.

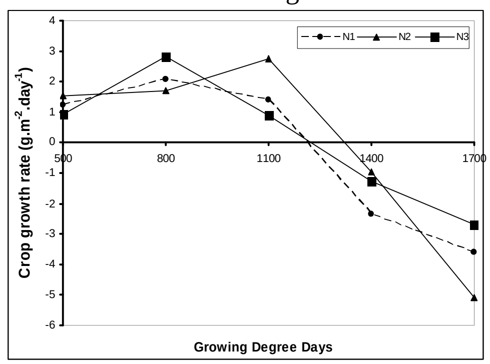

Fig. 11. Crop growth rate (CGR) of sunflower at different levels of nitrogen.

Figures (12) and (13) show relative growth rate (RGR) for both plants at different levels of nitrogen. Relative growth rate is high at early growth season and gradually, as plant grows and shading increases and meristem cells reduce compared with mature cells, it shows a linear descending trend. Relative growth rate changes according to plant photosynthesis and respiration conditions and thus over the time and due to plant growth and the increase of respiration rate at end of growth season it gets negative. In this experiment, relative growth rate has got negative after 1500 growing degree days for both maize and sunflower. Highest rate of RGR for both plants belongs to treatment with application of 150 $kg.ha^{-1}$ nitrogen and S_2 planting pattern which is 0.021 $g.m^{-2}$ per GDD for maize and about 0.0026 $g.m^{-2}$ per GDD for sunflower.

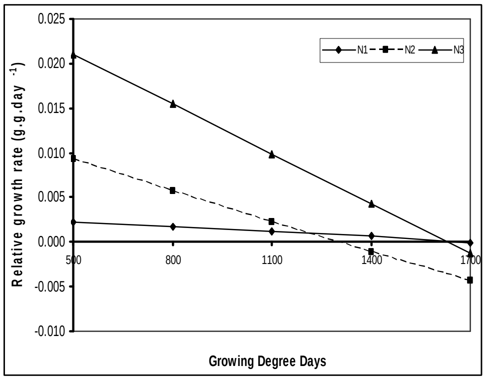

Fig. 12. Relative growth rate (RGR) of maize at different levels of nitrogen.

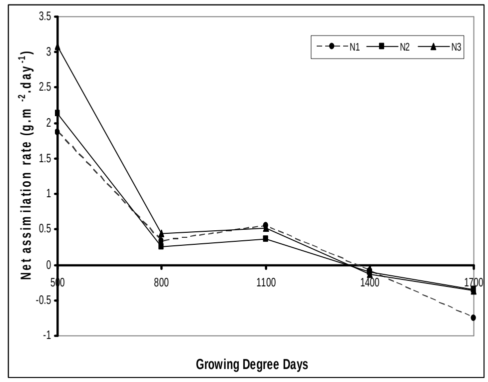

Fig. 14. Net assimilation rate (NAR) of maize at different levels of nitrogen.

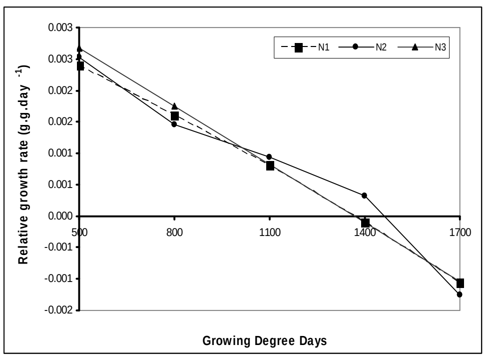

Fig. 13. Relative growth rate (RGR) of sunflower at different levels of nitrogen.

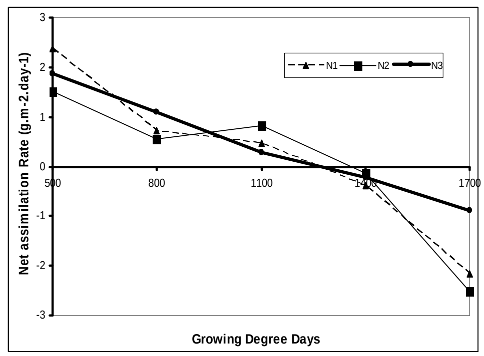

Fig. 15. Net assimilation rate (NAR) of sunflower at different levels of nitrogen.

Figures (14) and (15) show net assimilation rate (NAR) for both plants at different levels of nitrogen. The figures follow the general pattern of NAR curve. Highest net assimilation rate is observed in the early growth season when there is minimum shading, and then over time and as plants grow more and shading increases, it decreases until it gets negative in 1300 to 1400 growing degree days as leaves fall and leaf area index decreases. The highest rate of NAR in each plant belongs to the treatment with application of 150 $kg.ha^{-1}$ nitrogen. Results of experiment showed that except the treatment with 50% maize and 50% sunflower and 50 $kg.ha^{-1}$ nitrogen and the treatment with 25% sunflower and 75% maize and 50 $kg.ha^{-1}$ nitrogen, all intercropping treatments at all levels of nitrogen fertilizer were superior to monoculture system.

Maximum additional crop (16% compared with monoculture) was achieved in the treatment with 75% sunflower and 25% maize and consumption of 150 $kg.ha^{-1}$ nitrogen (S_2N_3) and LAI, CGR, RGR, and NAR indices in this treatment were more than those of the other intercropping treatments. With application of 150 $kg.ha^{-1}$ nitrogen the minimum additional product was achieved in S_4 treatment (75% maize and 25% sunflower) and with the increase of sunflower ratio in intercropping (25% maize and 75% sunflower), sunflower dominance increased the product about 9.3%.

CONCLUSION

High LER in most intercropping patterns confirms the point that plants in intercropping system make more and better use of environmental factors

(Blackman, 1919; Weil Ray and Macfaden, 1991). In intercropping 75% sunflower and 25% maize and 50 kg nitrogen the rate of obtained yield was 3% more than that of monoculture system and as nitrogen level increased up to 150 kg.ha^{-1} this superiority increased, too. It can be concluded that under proper and improper environmental conditions (in terms of soil nitrogen level) intercropping method is superior to monoculture method.

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