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ORIGINAL ARTICLE

Growth, N-uptake and Yield Attributes of Sunflower Plants Grown on an Aridisols in Response to N-fertilizer

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A field experiment was conducted to study the impact of different nitrogen fertilizer rates (0, 50, 100 and 150 kg N/ha as urea) on dry matter yield, nitrogen uptake (N), seed yield, seed oil content and properties of sunflower using the ^{15}N labeling technique. Sunflower plants responded to increasing N supply with respect to growth performance. Dry matter yield (DM) and total N uptake were significantly increased with increasing N-supply. Regardless of N-fertilizer rates, partitioning of N yield in different plant parts showed that capitulum was the principle sink of N (60%) followed by leaves (30%) and stem (10%). Seed yield was significantly increased at higher N-supply. However, seed oil content was reduced in the N-fertilized treatments. Decreasing of seed oil content due to N addition was overcompensated by the seed yield increase. Consequently, oil yield was almost the same amongst all treatments. No clear trend of the effect of N supply on oil quality parameters was observed. Nitrogen derived from fertilizer (Ndff) was significantly increased with increasing N-supply. Regardless of N fertilizer rate, mean value of the %^{15}NUE was 64%. This efficiency was less pronounced in stem and leaves than that in capitulum which had a greater value (69%) at higher N-supply.

Key words: Sunflower; N-fertilizer; Oil; 15N

Sunflower (*Helianthus annuus* L.) is one of the most important oilseeds particularly in human nutrition that contribute considerably to edible oil in the world and adapted to a wide range of climatic conditions (Toosi and Azizi, 2014). Sunflower seeds provide about 10% of all edible vegetable oil in the world (Seiler *et al.*, 2017; Irum *et al.*, 2019). This crop may contribute to the improvement of food security in edible oils through developing cultivars, enhancing agricultural system management (Kurdali, 2009) and optimizing the crops management including nitrogen fertilization. Nitrogen (N) is one of the important nutrients that enhances the metabolic processes based on protein, leads to increases in vegetative reproductive growth and yield of the crop. Proper nitrogen application optimizes seed yield and oil quality of sunflower plants (Zheljazkov *et al.*, 2008; Scheiner *et al.*, 2002). Many previous studies show that high or low amounts of applied N fertilizer have a negative impact on plant growth. Moreover, N fertilizer must be applied rationally in order to avoid a negative ecological impact and undesirable effects on the sustainability of agricultural production systems (Toosi and Azizi, 2014). High application rate of N fertilizers also affects the farmer's economy (Zubillaga *et al.*, 2002). Thus, appropriate amount of N-fertilizer must be need for better crop growth and quality (Ahmad *et al.*, 2018). Research information regarding the effect of N-fertilizer on growth, oil content and oil yield of sunflower in the semi-arid conditions of Syria are scarce. The objective of the present study was to determine the optimum N-fertilizer level, which could effectively improve the sunflower growth parameters, and yield attributes grown on an Aridisols under Syrian semi-arid conditions.

MATERIALS AND METHODS

Site Description, Soil Properties and Plant Materials

A field experiment was conducted at the research field of "Deir AL-Hajar" station located southeast of Damascus, Syria (36° 28'E, 33° 21' N; altitude 617 m). The site is located within a dry Mediterranean semiarid area with hot-dry summer and cold winter. According to U.S. soil taxonomy, the soil is categorized as Aridisol. Soil texture was sandy clay (50.4% sand, 13.1% silt and 36.5% clay) with an average of pH 8.6, Ec_e 0.16 dS/m, organic matter 0.82%, available P 10.8 µg /g, NH_4^+ 8.3 µg /g, NO_3^- 4.6 µg /g and total N 0.7 mg/g of the top 25 cm. The average minimum temperature in winter is 1.3 °C in Jan., while it increases to an average of 36 °C during August.

Seeds of sunflower plants *(Helianthus annuus*) were hand sown to a depth of about 3 cm in the first week of July, in rows with row- to- row distance of 40 cm and plant-to-plant distance of 20 cm. The experimental design was a randomized complete block design with four replicates; each plot was 5×5m.

Surface irrigation was initiated immediately after sowing. Irrigation was scheduled according to soil moisture content that was determined by neutron scattering (CPN 503 DR) in access tubes installed to 105 cm depth in four replicates in a central row of each treatment. Soil moisture content was measured at 15 cm consecutive depths.

Treatments and ^{15}N Application

The treatments consisted of four levels of N (0, 50, 100, and 150 kg N ha^{-1}, abbreviated as N0 , N50 , N 100, and N 150, respectively). These treatments were laid out in a Randomized Complete Block Design (RCBD) with four replications. After seedling emergence, a 500-mL solution of urea, (1%^{15} N atom excess) was uniformly sprayed on a 1 * 1.2m subplot at the center of each main plot. The remaining plot area was similarly treated with the same amount of un-labelled urea fertilizer. The N fertilizer was applied in two equally split applications (i.e. third and eleventh true leaves, Montemurro and De Giorgio 2005).

Plant Sampling and Isotopic Compositions Analyses

Plant samples were harvested at 85 days after planting (DAP) coinciding with the physiological maturity stage. Whole aboveground plant samples were collected from the corresponding subplots by cutting the main stem immediately below the cotyledonary node, then separated into its main components (shoots , stems and reproductive parts), dried at 70 °C, weighed and ground to a fine powder using a mill having a 0.5 mm sieve.

Total nitrogen was determined by Kjeldahl procedure, and $^{15}N/^{14}N$ isotope ratio was measured with an emission spectrometer (Jasco-150, Japan). Percent (%) and amount (kg ha^{-1}) of N derived from fertilizer (Ndff), from soil (Ndfs) and nitrogen fertilizer use efficiency (%NUE) were calculated using the ^{15}N isotopic data by applying equations previously described (Zapata 1990). Moreover, grain and oil yields was determined at maturity (115 DAP). Oil content (mg g^{-1}) was determined in sunflower seeds as extractable component in Soxhelt apparatus using standard method (A.O.A.C, 1990).

Statistical Analysis

Collected data were subjected to analysis of variance (ANOVA) using the statistical program Statview, 4.57® Abacus Concepts, Berkley, Canada. Means were compared using the least significant difference (Fisher's LSD) test at a probability level of $P<0.05$.

RESULTS AND DISCUSSION

Effect of N Fertilizer on Dry Matter Yield and N Accumulation

Dry matter yield (DM), N content and accumulation in different plant parts of sunflower as affected by different rates of N fertilizer are shown in Table 1. DM and N yield were increased in different plant parts with increasing rates of N fertilizer. Proportion of DM increments were 30, 70 and 81% in leaves; 32, 20 and 38% in stems; and 9, 18 and 44% in the reproductive part (capitulum) over the control (N0) in N50, N100 and N150 treatments, respectively. Similarly, N yield values were 45, 90 and 126% in leaves; 56, 62 and 130% in stems; and 10, 38 and 79% in capitulum higher than the non-fertilized control treatment for the above mentioned treatments, respectively.

Data of total DM and N yield are shown in Fig. 1. DM yield in the non-fertilized control treatment was 9.7Mg ha^{-1}, and increased to 11.8, 12.5 and 14.57 Mg ha^{-1} in N50, N100 and N150 treatments, respectively. In comparison with the control, the percent increments of total DM were 22, 29 and 49%, respectively. Similarly, total N accumulation in the entire sunflower plant was 137 kg N ha^{-1} in the control. Application of N fertilizer resulted in increasing N yield by 24, 55 and 96% in N50, N100 and N150 treatments, respectively. Their actual values were 170, 212 and 269 kg N ha^{-1}, respectively. Overall, our results showed that there was a gradual increase in DM and N yield of sunflower being maximum (14.6Mg ha^{-1} and269 kg N ha^{-1}, respectively) with 150 kg N ha^{-1}. Consistent with our results, there are many reports in the literature observed that there was a gradual increase in yield attributes of sunflower plants worldwide (Montemurro and De Giorgio, 2005; Abbadi *et al.*, 2008; Nasim *et al.*, 2012; Ghani *et al.*, 2000). Ayub *et al.*, (1998) reported that plant height, leaf area per plant, stem diameter, number of seed per disc and achene protein contents of sunflower plants were maximum at applying of 150 kg N ha^{-1}, similar good achene yield was achieved with nitrogen 100 and 150.

Partitioning of Dry Matter and Nitrogen Yield

Although N fertilizer increased both DM and N yield, their distribution varied among plant parts (Fig. 2). Regardless of N fertilizer, partitioning of DM was the lowest in leaves (23% of total DM yield), whereas, they were 37% and 40% in stems and reproductive part (capitulum), respectively. It is worth mentioning that partitioning of DM in leaves significantly increased in N100 (26%) and N150 (24%) treatments as compared with N0 (20%) and N50 (21%) treatments (Fig. 2). Partitioning of N yield in stems, leaves and reproductive parts were 10, 30 and 60%, respectively, regardless of N fertilizer levels. Hocking and Steer (1983) reported that leaves were the most important reservoir of nitrogen despite a much smaller contribution to plan dry matter. The higher partitioning rate of stem's DM (37%), with the lowest partitioning rate of their nitrogen yield (10%) might be resulted from its low N content (between 3.4 and 5.7 mg N g^{-1}) as compared with leaves (between 18.6 and 23.1mg N g^{-1}). Whereas, N content in the reproductive parts ranged between 21.6 and 26.9 mg N g^{-1}(Table 1). Therefore, it can be concluded from the above-mentioned data that the reproductive parts seemed to be the major sink of N. Accordingly, the redistribution of N from vegetative parts was important in seed filling during the last stage of plant growth and development (Hocking and Steer 1983).

Effect of N Fertilizer on Seed Yield, Oil Content and Its Properties

Seed yield of sunflower plants was significantly affected by N fertilizer levels (Fig. 3). They ranged between 2.8 Mg ha^{-1} in the control and 3.4 Mg ha^{-1}in N150 treatment (i.e. 21% percent increment over the control). However, seed oil content decreased in the N-fertilized treatments. Mean values of oil content were 536, 493, 461 and 476 mg/g for N0, N50, N100 and N150 treatments, respectively (Fig. 3) with no significant differences among the fertilized treatments. Nevertheless, mean value of oil yield was around 1.5 Mg ha^{-1} without any significant effect of N-fertilizer being obtained. It is worth mentioning that the reduction in seed oil content (mg g^{-1}) in response to N supply (Fig. 3) was accompanied by increasing N contents (mg g^{-1}) and N yield (kg ha^{-1}) in the different parts of sunflower plants (Table 1). Thus, decreasing of seed oil content due to N addition was overcompensated by the seed yield increase. Consequently, no significant effect of N supply on oil yield was observed.

Consistent with our results, many previous researches (Sharma and Verma 1982; Abbadi *et al.* 2008) reported that the oil concentration of sunflower was reduced at higher N supply. Such a reduction might be resulted from the dilution of oil in heavier achenes produced under high N nutrition, which in further supported by increased achene N concentration. However, the reduction did not offset the positive effect of large N supply on increasing oil yield so that sunflower oil yield remain positively related to N application even at high supply.

Some oil properties in sunflower seeds in response to N fertilizer supply are shown in Table 2. There were no significant changes in there refractive index, acid value, saponification of lipid and peroxide value. However, a slight decline in iodine number was observed in the N100 treatment. Hence, it can be concluded that application of N fertilizer to sunflower plant did not result in substantial changes of oil properties. Ahamad *et al.* (2018) concluded that increasing the nitrogen level has positive effect on sunflower growth, but also has a negative impact on some of its quality parameters. Therefore, an appropriate rate of nitrogen fertilizer is needed and must be determined in wide range of climatic conditions for better of plant growth and quality. In the Savanna Alfisols, Oyinlola *et al.* (2010) reported that excess N reduced seed yield and oil contents as well as delayed flowering of sunflower. The optimum N requirement of sunflower obtained from their study was about 100 kg N ha^{-1}.

Effect of N Fertilizer on Nitrogen Uptake from the Available Sources

The mean values of ^{15}N-atom excess (^{15}N a.e %), proportions and amounts of nitrogen derived from soil (Ndfs), from fertilizer (Ndff) and N use efficiency of added fertilizer in different parts of sunflower plants are shown in Table 3, whereas Fig. 4 shows Ndfs and Ndff values in the whole plant.

Values of the ^{15}N-atom excess significantly increased with increasing N fertilizers indicating that a significant portion of plant N is derived from fertilizer. %Ndff values ranged between 17 and 39% (Table 3 & Fig. 4). Proportions and amounts of Ndff in the whole plant were increased with N supply rates (Fig.4). However, proportions of Ndfs were decreased with increasing rates of N fertilizer, while the opposite was true for total amount of Ndfs. In the whole plant, total amounts of Ndff were 30, 64 and 104 kg N ha^{-1}in N50, N100 and N150 treatments, respectively. Moreover, total amounts of Ndfs were 140, 148 and 165 kg N ha^{-1}in N50, N100 and N150 treatments, respectively.

The soil nutrient supply measured in terms of availability units of applied fertilizer N has been referred to as “A-value”. According to the IAEA (1983), the “A value” is based on the concept that when a plant is confronted with two or more different sources of a given nutrient, it will absorb from each source in direct proportion to the respective quantities available to the crop which can be determined as following:

A value of soil= (Ndfs/Ndff) × Fertilizer nutrient applied

This study showed that The A value remained constant (around 236 kg N/ha) at different rates of applied labelled nitrogen fertilizer (Fig. 5). Thus the A values obtained with the isotope method are not affected by different rates of N application (IAEA1983)

Nitrogen Use Efficiency (%NUE)

The nitrogen use efficiency (%NUE) is defined as the capacity of a given plant species in taking an advantage of the applied nitrogen fertilizer and transform it in biomass. The evaluation of NUE is useful to determine the plant ability to absorb and utilize nutrients for maximum yields (Baligar *et al.* 2001).

Nitrogen fertilizer use efficiency (%NUE) was calculated as fertilizer N recovery in each plant part (Table 3) and in the whole plant of sunflowers (Fig.5). Regardless of N fertilizer rate, mean values of the %NUE were 20%, 67% and 37% in leaves, stems and capitulums, respectively, with no significant differences being obtained in leaves and stems (Table 3). In the reproductive part (capitulums), NUE significantly increased with increasing N fertilizer rate. Their actual values were 34.5, 36, and 41.3% in N50, N100 and N150 treatments, respectively. These results indicate that capitulum is the main sink of the added N fertilized, followed be leaves and stems. In the whole above ground part, NUE% values were 60, 63.6 and 69.2% in N50, N100 and N150 treatments, respectively (Fig. 5). Regardless of N fertilizer rates, mean value of NUE was 64%. This value is under-estimated since we did not take into account the roots.

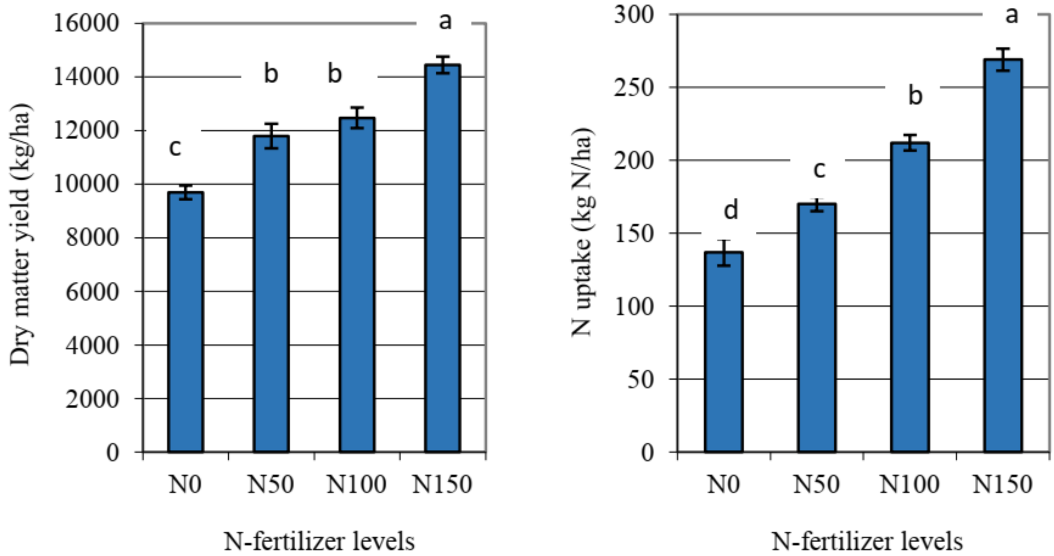

Figure 1: Dry matter yield (DM), N uptake in the whole plant of sunflower in response to N fertilizer

Table 1. Dry matter yield (DM), N content and accumulation in different plant parts of sunflower as affected by different rate of N fertilizer

Treatment	DM (Mg ha^{-1})	N-content (mg g^{-1})	N- uptake (kg ha^{-1})
Leaves			
N0	1.91c	18.6b	35.4c
N50	2.49b	20.7ab	51.5b
N100	3.24a	20.8ab	67.3a
N150	3.46a	23.1a	80.0a
$LSD_{0.05}$	*0.44*	*2.7*	*12.8*
Stems			
N0	3.64c	3.4c	12.4c
N50	4.79a	4.1bc	19.5b
N100	4.36b	4.7b	20.1b
N150	5.04a	5.7a	28.6a
$LSD_{0.05}$	*0.42*	*0.8*	*3.39*
Reproductive part (capitulums)			
N0	4.14c	21.6b	89.6c
N50	4.51bc	22.4ab	99.0 c
N100	4.87b	25.6ab	124.0b
N150	5.95a	26.9a	160.0a
$LSD_{0.05}$	*0.56*	*5.2*	*17.9*

Means within a column followed by the same letter are not significantly different (P>0.05).

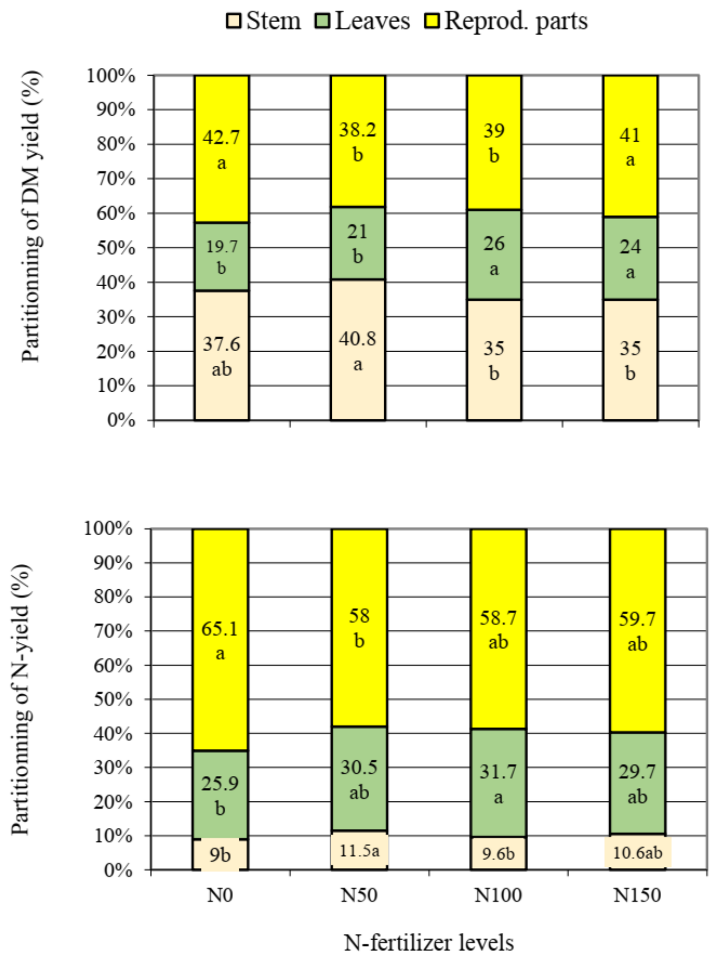

Figure 2: Partitioning of dry matter (DM) and N- yield among plant parts of sunflower in response to N fertilizer

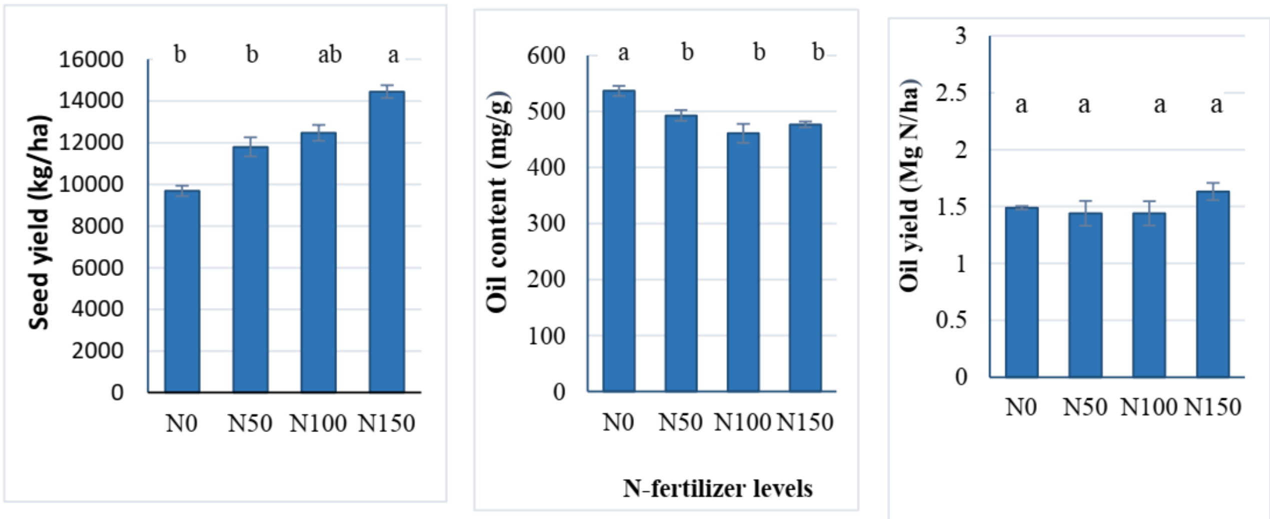

Figure 3: Seed yield (kg/ha), oil content (mg/g) and oil yield (Mg/ha) of sunflower plants in response to N fertilizer

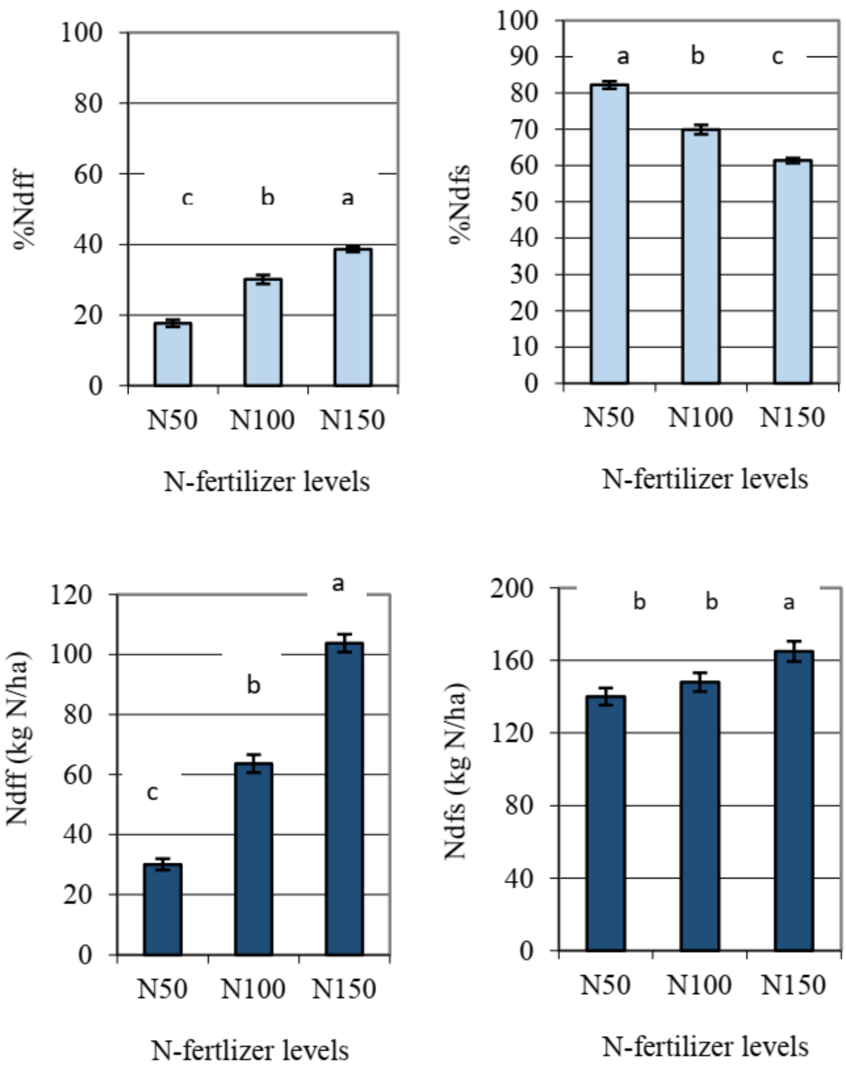

Figure 4: Nitrogen uptake from the fertilizer (Ndff) and from soil (Ndfs) in the whole plant of sunflower in response to N fertilizer

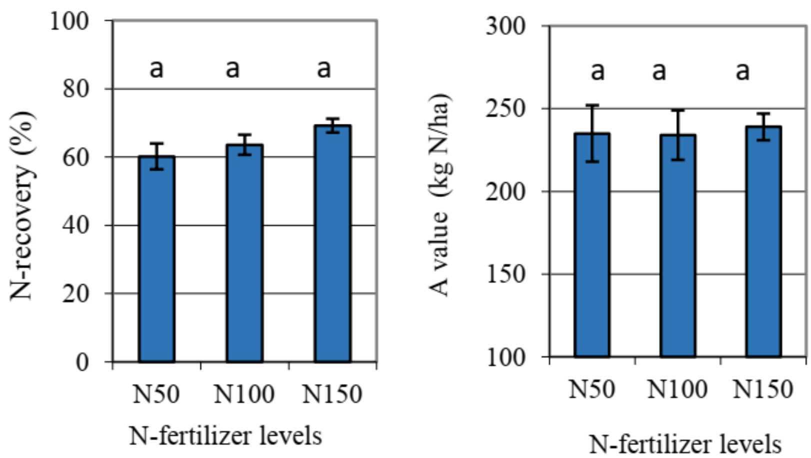

Figure 5: Nitrogen Use Efficiency (%N-recovery) in the whole plant of sunflower and "A values" of soil amended with different rates of N-fertilizer (kg N/ha)

Table 2. Some oil properties in sunflower seeds in response to N fertilizer supply

Treatment	Peroxide value (meq O_2/kg oil)	Iodine number (mg I/100g oil)	Saponification (mg KOH/g oil)	Free fatty acid (%)	Refractive index at 25ºC
N0	16.6a	110a	191a	0.87a	1.47a
N50	18.8a	110a	192a	0.68a	1.47a
N100	17.5a	101b	195a	0.85a	1.47a
N150	15.0a	107ab	193a	0.79a	1.47a
$LSD_{0.05}$	*N.S*	*8.7*	*N.S*	*N.S*	*N.S*

Means within a column followed by the same letter are not significantly different (P>0.05).

Table 3. Mean values of ^{15}N-atom excess (^{15}N a.e %), proportions and amounts of nitrogen derived from soil (Ndfs), from fertilizer (Ndff) and N use efficiency of added fertilizer in different parts of sunflower plants in response to N fertilizer supply

Treatment	%^{15}N a.e	Ndff		Ndfs		(%) N recovery
		%	kg/ha	%	kg /ha	
Leaves						
N50	0.1824c	18.2c	9.5c	81.8a	42.1a	18.9a
N100	0.3209b	32.1b	21.6b	67.9b	45.7a	21.6a
N150	0.3873a	38.7a	31.0a	61.3c	49.1a	20.7a
$LSD_{0.05}$	*0.027*	*2.7*	*4.7*	*2.7*	*N.S*	*N.S*
Stem						
N50	0.1743c	17.4c	3.4c	82.6a	16.1ab	6.8a
N100	0.2963b	29.6b	6.0b	70.4b	14.2b	6.0a
N150	0.3782a	37.8a	10.8a	62.2 c	17.8a	7.2a
$LSD_{0.05}$	*0.039*	*3.9*	*1.26*	*3.9*	*2.7*	*N.S*
Reproductive part (capitulums)						
N50	0.1761c	17.6c	17.2c	82.4a	81.8b	34.5b
N100	0.2912b	29.1b	36.1b	70.9b	88.0ab	36.ab
N150	0.3874a	38.7a	62.0a	61.9c	98.0a	41.3a
$LSD_{0.05}$	*0.041*	*4.07*	*5.1*	*4.07*	*15.7*	*5.4*

Means within a column followed by the same letter are not significantly different (P>0.05).

CONCLUSION

The results of this research indicate that nitrogen fertilizer had a significant effect on sunflower growth and yield parameters. The following conclusions were obtained from this research:

- From a productivity standpoint, the optimum N fertilizer rate for sunflower plants obtained from this study was 150 kg N ha^{-1}. This treatment surpassed the others in terms of total DM, N, seed yield and oil yield with suitable oil content, and exhibited a higher N use efficiency of the added fertilizer (69%).
- From economic and environmental standpoints, the optimum rate of N fertilizer could be between 50 and 100 kg N ha^{-1} to ensure suitable growth, yield parameters and lower consumption of soil nitrogen along with reducing synthetic N fertilizer use contributing to GHG mitigation and less environmental damage at relatively low costs.

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CONFLICTS OF INTEREST

The authors declare that they have no potential conflicts of interest.

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