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Nitrogen dynamics, growth, yield and quality of sunflower (*Helianthus annuus* L.) under the influence of soybean (*Glycine max* L.) intercrop

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Abstract

Abstract

Intercropping of a leguminous crop in non-legume affects its nitrogen dynamics. Field research was conducted at the farm area of College of Agriculture, University of Sargodha. To understand whether soybean intercropping alters the nitrogen use efficiency, yield and quality of sunflower, a field study was conducted at College of Agriculture, University of Sargodha, Pakistan during spring, 2022. Treatments were varying N application rates (0, 40, 80, 120 and 160 kg ha^{-1}). A randomized complete block design was used with four replications. Hysun-33 and NARC-21 were the hybrids of sunflower and soybean, respectively. Soybean rows were spaced 30 cm apart whereas sunflower row spacing was 60 cm. In each plot, 4 rows of sunflower were altered by 3 rows of soybean. Results revealed significant improvement in growth and yield of sunflower by increase in N application. The highest N level (160 kg ha^{-1}) resulted in the highest number of days (114.7) the sunflower crop took to reach maturation. The same treatment attained the highest plant height (214.5 cm), leaves per plant (27.5), leaf area index (4.39), head diameter (25 cm) and biological yield (14789 kg ha^{-1}), number of achenes per head (1586), 1000-achene weight (51.25 g), harvest index (16.94%), achene yield (2395 kg ha^{-1}) and oil yield (872.0 kg ha^{-1}). The highest nitrogen use efficiency (7.2 kg kg^{-1}) of sunflower was calculated at 80 kg ha^{-1} N level. It can be concluded that for getting the highest yield of sunflower crop along with soybean

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intercrop, farmer should use 160 kg ha^{-1} nitrogen. However, in soybean intercropping system, the maximum yield benefit of sunflower per unit of nitrogen applied was the highest at 80 kg nitrogen per ha.

Keywords: Achene yield, intercropping, leguminous crop, nitrogen use efficiency

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Introduction

Sunflower (*Helianthus annuus* L.) is a member of the *Asteraceae* and one of over 60 species in the genus *Helianthus* (Andrew et al., 2013). The Greek words *helios* (the sun) and *anthos* (flower) make up the term helianthus (a flower). The name *Sunflower* explains the idea that the plant's inflorescence usually faces towards the Sun (Vandenbrink et al., 2014). It is third most significant oilseed crop of Pakistan after cotton, rapes and mustards and its contribution in local oil production is 11%. It can easily fit within the majority of the cropping systems in country due to its flexibility of being grown in both the spring and the autumn season. However, the spring crop is widespread. Sunflower seed which is botanically called achene contains around 38% oil and 18% protein. Sunflower oil is rich in two essential amino acids, oleic acid (19%) and linoleic acid (64%) (Petraru et al., 2021). Pakistan has seen a growth in sunflower area, seed output, and oil production this year, with increases of 76%, 62%, and 63%, respectively (Government of Pakistan, 2021). Due to lower local production of edible oil, we spend Rs.662.657 billion annually on its import. Sunflower has been recognized as a crop with a great potential to satisfy future oil demand of country. Sunflower plant needs around 120 days without frost. While it can survive temperatures between 8 and 34°C, between 20 and 25°C is the optimal range for better development and production (Shah et al., 2005). In both irrigated and rain-fed locations, sunflower may be grown across the Punjab. Most important districts regarding production of sunflower in Punjab are Lahore, Sheikhupura, Kasur, Multan, Rahim yar Khan, Rajanpur, D.G. Khan, Vehari, Bahawalpur, Muzaffargarh, Rawalpindi, Gujrat, Sialkot, Sahiwal, Okara, Sargodha and Faisalabad.

Soybean (*Glycine max* L.) is an important leguminous crop which is primarily farmed for seed production. It is an erect branching plant that can reach up to 2 m height. It produces self-pollinating flowers that are white or with a purplish shade color. Fruits are called pods that bear 1-4 seeds that may be yellow, green, brown, black, or bicolored. Its seed is a high source of protein (approximately 40%) and provides sustenance for both humans and animals. The seeds also contain roughly 18-22% edible oil, which can help us meet our needs for oil (Clemente and Cahoon, 2009). Soybean as an oilseed crop was introduced in Pakistan during early 1960s. Punjab, Khyber-Pakhtunkhwa (KPK) and Sindh were found most suitable for soybean cultivation (Asad et al., 2020). The demand for soybean is rising on both national and global scale due to its multiple uses. Soybean meal is used in poultry, livestock and aquaculture industry, and its oil is among the most widely consumed cooking oils in world. The developing dairy and poultry industry in Pakistan has increased the demand for soybean. However, due to lower production at local level the soybean import during the last 5 years has been raised by 118% (USDA, 2021). Despite the greater importance of this crop, soybean crop has not become a successful crop of Pakistan. The reasons are absence of high-yielding, stress resistant varieties, lack of its advanced production technology and poor marketing of its produce. Intercropping of soybean in our major summer and spring season crops is a viable option to enhance its production without reducing the cultivated area of existing crops like maize, sugarcane, sunflower etc. Thus farmer’s economic benefit can be increased. Moreover, being a leguminous nitrogen fixing crop, soybean could add some nitrogen in soil thus nitrogen fertilizer can be saved by its reduced input need without compromising yields of main crop. Keeping in view, study was planned to investigate the effect of soybean intercrop on the growth, yield, quality and nitrogen dynamics of sunflower.

Materials and Methods

Site and soil

Field research was carried out at research area, College of Agriculture, University of Sargodha, Sargodha-Pakistan. The experimental site was located at 32°N, 72°E and at 190 m height from sea. The soil was clay loam having good drainage ability. The soil was examined by taking samples before planting. Soil auger was used to gather samples at 10 and 20 cm depths. The soil type was sandy loam. Table 1 shows physio-chemical parameters of soil.

Table 1. Physio-chemical analysis of soil from experimental area

Characteristics	**Soil Sample Depth**		
	30 cm	**60 cm**	**Mean**
Soil pH	7.6	7.9	**7.75**
Organic matter (%)	0.68	0.59	**0.63**
Nitrogen (%)	0.42	0.30	**0.36**
Available P (ppm)	6.78	9.58	**8.18**
Extractable K (ppm)	143	128	**135.5**
Texture class	**Clay loam**	**Clay loam**	**-**

Meteorological data

Weather data of the growing phase (February-July) during study year (2022) have been presented in Figure 1. Data indicated that minimum monthly average temperature was 15.5ºC in the month of February whereas maximum temperature of 34.1ºC prevailed in the month of May.

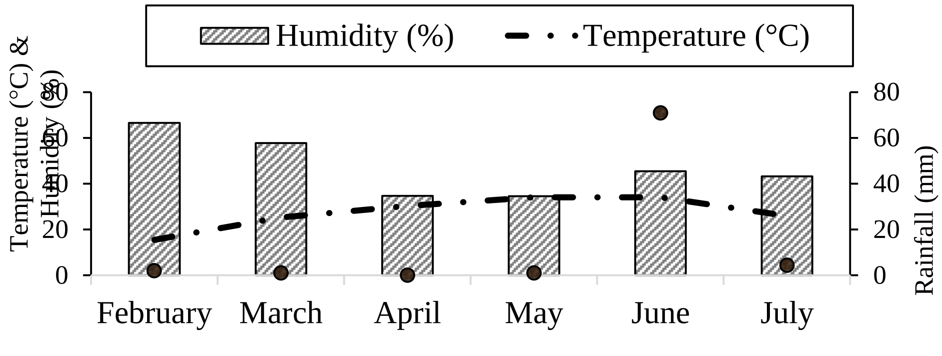

Figure 1. Meteorological data of the crop growing season

Experimental design and treatments

Experimental treatments comprised of five different nitrogen doses (0, 40, 80, 120, 160 kg ha^{-1}) that were arranged in randomized complete block design with four repetitions. The net plot size was 2.4 m × 1.5 m. In each plot, 4 rows of sunflower were altered by 3 rows of soybean.

Crop husbandry

Seed of Hysun-33 hybrid of sunflower was collected from local market whereas of NARC-21 hybrid of soybean was collected from National Agriculture Research Centre (NARC), Islamabad. Both the sunflower and soybean crops were sown on 19^{th} February, 2022. The land was prepared by ploughing twice with tractor mounted plough each followed by planking. Both the crops were sown maintaining row to row distance of 30 cm with the help of single row hand drill and plant to plant distance of 20 cm with the help of thinning before first irrigation. Before sowing of seed and before the land preparation, one bag of di-ammonium phosphate (DAP) per acre was broadcasted in the field and after that land was ploughed. Plot bunds were made just after sowing. First irrigation was applied 20 days after crop emergence (DAE), second irrigation was applied 40 DAE, third at head formation and fourth at seed formation. Nitrogen in the form of urea as basal application, second split application with first irrigation, third split application with second irrigation according to treatment plan. The harvesting of both crops was accomplished within the first week of July, 2022.

Observations and data recording

Data related to plant growth, yield and yield related traits of sunflower were recorded as described below:

Days to maturation: Days to maturity were recorded when backs of about 95% heads turned yellow and outer bracket turned brownish.

Leaf area index: Leaf area index was determined through recommended formula, as ratio between area of leaf and area of land as recommended by Watson (1952). Leaf area of leaves harvested from mature crop near harvesting was calculated through leaf area meter (Yaxin-1241 Leaf Meter).

$$LAI = Leaf\ area\ /\ Land\ area$$

Plant height (cm): Plant height was taken at maturity stage. About five plants from a randomly placed quadrate were selected from each plot. For measuring height, meter rod was used. Height was taken from soil surface to the apex of plant and then mean was calculated.

Number of leaves per plant: For number of leaves per plant, ten plants were selected randomly from each treatment and leaves per plant were counted and then average was calculated.

Head diameter (cm): After crop harvesting, sunflower head diameter was measured with the help of measuring tape.

Number of achenes per plant: To record the number of achenes, randomly ten plants were chosen from each treatment. Number of achenes was calculated and then mean was determined.

1000-achene weight: For taking 1000-achene weight, required number of achenes were taken randomly from every treatment and weighed through electronic balance.

Biological yield (kg ha^{-1}): At maturity, randomly selected plants from one square meter were collected, dried and then weighed-up. Biological yield was determined in kg per hectare.

Achene yield (kg ha^{-1}): To calculate achene yield, we winnowed dehydrated heads. Then achenes were cleaned and weighed. The data was changed into kg per hectare.

Harvest index: Harvest index was calculated by using the following formula:

$$Harvest\ index = \frac{Achene\ yield\ (kg\ per\ ha)}{Biological\ yield\ (kg\ per\ ha)} \times 100$$

Oil yield (kg ha^{-1}): Data of achene yield was multiplied with respective oil contents of each treatment to get oil yield. Oil content was determined through Soxhlet's apparatus (WiseTherm).

Nitrogen use efficiency (kg kg^{-1}): Nitrogen use efficiency (NUE) of sunflower in each treatment was calculated by using theformula suggested by Fageria & Baligar (2005):

$$NUE = \frac{achene\ yield\ of\ fertilized\ plot - achene\ yield\ of\ control\ plot}{Nitrogen\ applied}$$

Statistical analysis

Data of all parameters was subjected to Fisher's analysis of variance technique and data means were separated with Tukey's honestly significance test (HSD) at 5% probability level (Steel et al., 1997). Statistix 8.1 software (Statistix 8.1, Tallahassee, Florida, USA) was used for analyzing data.

Results

Sunflower growth: Data relevant to growth traits of sunflower including days to maturation, plant height, number of leaves per plant, leaf area index, head diameter and biological yield with soybean intercrop at different nitrogen rates are presented in Table 2. Data showed that all the growth parameters of sunflower were gradually improved in response to increasing N levels. Significantly the highest values of plant height (214.5 cm), number of leaves per plant (27.5), leaf area index (4.36), head diameter (25 cm) and biological yield (14789 kg ha^{-1}) of sunflower were recorded with the highest N level (160 kg ha^{-1}). A significant delay by sunflower crop in reaching to maturation was also observed in response to increasing N levels (Table 2).

Table 2. Growth of sunflower with soybean intercrop as affected by variable N rates

Treatments	Days to maturity	Plant height (cm)	No. of leaves per plant	Leaf area index	Head diameter (cm)	Biological yield (kg ha^{-1})
T1=0	110.0 d	158.7 d	18.00 e	3.15 e	14 e	11558 e
T2=40	111.5 c	179.7 c	19.75 d	3.40 d	17 d	12175 d
T3=80	112.2 b	193.0 b	23.25 c	3.69 c	19 c	13064 c
T4=120	112.7 b	207.2 a	25.50 b	3.99 b	22 b	13825 b
T5=160	114.7 a	214.5 a	27.50 a	4.36 a	25 a	14789 a
LSD	**0.61**	**11.29**	**1.116**	**0.087**	**0.6**	**162.7**

Mean values in a column with different letters differ considerably (P < 0.05) from one another depending upon least significant difference (LSD) test.

The sunflower plants supplied with highest N level (160 kg ha^{-1}) took the highest number of days to maturation (114.7). The prolongation in maturity period of sunflower by the increase in nitrogen fertilization was probably the result of delayed maturity due to elongation in vegetative growth period. These results are in close resemblance to the results of Sridhar et al. (2006). The improvement in growth traits by increased nitrogen levels indicated an enhancement in vegetative growth of sunflower. As nitrogen is directly involved in delaying vegetative growth phase of plant, vegetative growth of sunflower was improved. The plant height is the most obvious indicator of its vegetative growth. More the vegetative growth of a plant, more will be its height. As nitrogen is directly linked with vegetative growth, an increased N supply therefore results in greater plant height (Xiao et al., 2006). These findings corroborate the results of Soleymani et al. (2016) and Angadi and Entz (2002) who demonstrated that as nitrogen dose was increased, height of plant gradually increased. The number of leaves a plant produces up to its maturity is usually linked with the height it attains. A long statured plant has therefore greater number of leaves than a short statured plant. Increase in number of leaves of sunflower with increased nitrogen supply was attributed to the increase in its plant height. Leaf number has a direct bearing on plant height (Abrar et al., 2010). These results are in line with findings of Oyinlola et al. (2010) and Perveen et al. (2011). Leaf area of a crop is the result of leaf number and leaf expansion. The increase in leaf area index of sunflower by increased nitrogen levels was probably due to more leaf number on account of vigorous vegetative growth. These results are similar to those of Ilham Ulla et al. (2016) and Fieuzal and Baup (2016). The enhanced sunflower head diameter in response to augmented N supply seems to be the result of greater vegetative growth of sunflower because head diameter is directly affected with vegetative growth (Mirzabe and Chegini, 2015). The outcomes of present study are supported by conclusions of Ilham Ulla et al. (2016), Sincik et al. (2013) and Arshad et al. (2007). Biological yield include all those plant produces throughout its growing season. Vegetative as well as reproductive growth of crop contribute to biological yield. In our study, all yield contributing traits (plant height, number of leaves, leaf area index and head diameter) of sunflower showed an increasing trend in response to increasing N levels. That is why, biological yield was also increased significantly by increasing N application rate. These results are not too much different from the result of Namvar et al. (2012), Jafri et al. (2015) and Modanlo et al. (2021).

Sunflower yield and yield related traits Data relevant to achene and oil yield and yield related traits of sunflower with soybean intercrop under different nitrogen application rates have been presented in Table 3. It is clear from the data that number of achenes per head, 1000-achene weight, harvest index, achene yield and oil yield of a sunflower were gradually increased in response to increasing N levels from 0 to 160 kg ha^{-1}. Consequently, the highest N dose (160 kg ha^{-1}) attained significantly the highest achene number per head (1586), 1000-achene weight (51.25 g), harvest index (16.94%), achene yield (2395 kg ha^{-1}) and oil yield (872 kg ha^{-1}). As the nitrogen supply to sunflower crop was increased, nitrogen uptake was also increased that resulted in improvement in the overall growth of crop. The larger head diameter probably resulted in greater number of achenes developed over the head. Our outcomes corroborate the results of Awais et al. (2015) who found significant improvement in number of achenes of sunflower by increasing nitrogen level up to 150 kg ha^{-1}. Ahmad et al. (2011) was also of view that soil supplied N fertilizer boosted up achene number in sunflower head.

Table 3. Yield and yield traits of sunflower with soybean intercrop as affected by variable N rates

Treatments	Achenes per head	1000-achene weight	Harvest index	Achene yield (kg ha-1)	Oil yield (Kg ha-1)
T1=0	691.5 e	32.75 e	12.10 d	1450 e	446.7 e
T2=40	898.8 d	38.50 d	14.53 c	1707 d	541.1 d
T3=80	1061.5 c	42.75 c	15.14 b	2026 c	678.7 c
T4=120	1329.8 b	48.00 b	16.19 a	2224 b	791.7 b
T5=160	1586.0 a	51.25 a	16.94 a	2395 a	872.0 a
LSD	**59.92**	**1.585**	**1.040**	**97.3**	**31.81**

Mean values in a column with different letters differ considerably ($P < 0.05$) from one another depending upon least significant difference (LSD) test.

The increment in 1000-achene weight of sunflower as a result of increased supply of N to crop might be due to enhancement in biological yield of crop. The increased assimilates supply to developing achenes by plants with greater biomass thus resulted in heavier achenes. These results are in close agreement with those of Soleymani et al. (2016) and Ahmad et al. (2018). The improvement in harvest index of sunflower by raised nitrogen supply to crop indicates that greater proportion of photosynthates produced by plants was partitioned in achenes. Nitrogen results in more efficient remobilization of assimilates to reproductive parts of plants (Gholinezhad et al., 2009). Present findings are verified by those of previous researchers (Nazir et al., 1987; Massignam et al., 2009). The increase in achene yield of sunflower with rise in nitrogen application rates seems to be the result of increment in number of achenes per head and 1000-achene weight of sunflower as both of these yield contributing traits prone to significant improvement by nitrogen application. The present findings are in close conformity to those of Ilham Ulla et al. (2016), Sincik et al. (2013) and Kosar et al. (2021). The boost-up in oil yield of sunflower in response to enhancement in nitrogen levels seems to be due to improvement in achene yield. This is due to fact that nitrogen has little or no effect on oil content of sunflower achenes (Lawal et al., 2011). These results very much resembled with those of Anandhan et al. (2010) and Shorstkii et al. (2017).

Data related to nitrogen use efficiency of sunflower at different N application rates has been depicted in Figure 2. A rapid increase followed by a gradual decrease in nitrogen use efficiency of sunflower was observed in response to increased nitrogen rate from 0 to 160 kg ha^{-1}. The highest nitrogen use efficiency (7.2 kg kg^{-1}) was calculated at 80 kg nitrogen per ha. However, by a further increase in nitrogen application rate, the nitrogen use efficiency was lowered down to 6.4 kg kg^{-1} at 120 kg ha^{-1} nitrogen and then to 5.9 kg kg^{-1} at 160 kg ha^{-1} nitrogen.

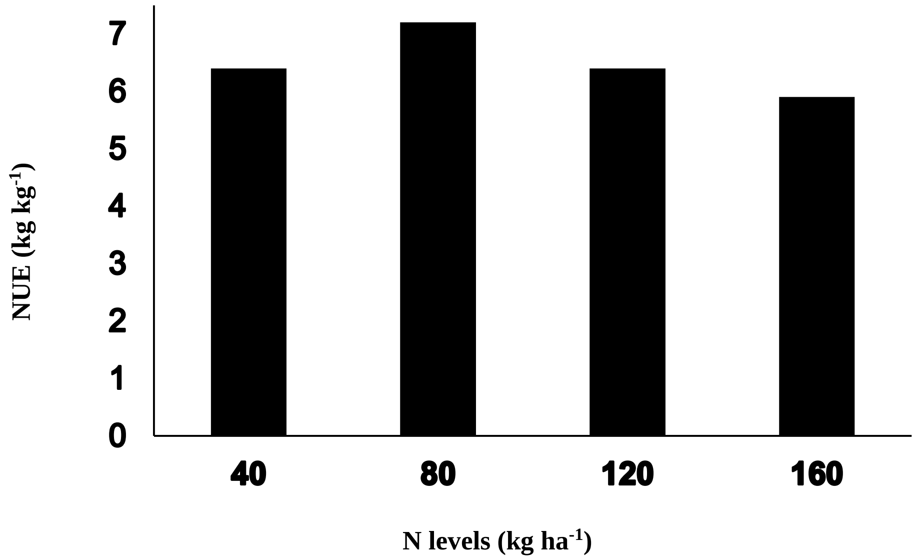

Figure 2. Nitrogen use efficiency (NUE) of sunflower with soybean intercrop at variable N application rates

Conclusion

From above presented results it can be concluded that for getting the highest yield of sunflower crop along with soybean intercrop, farmer should use 160 kg ha^{-1} nitrogen. However, in soybean intercropping system, the maximum yield benefit of sunflower per unit of nitrogen applied was achieved at 80 kg nitrogen per ha.

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