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OPTIMIZING NITROGEN RATE AND PLANTING DENSITY FOR SUNFLOWER UNDER IRRIGATED CONDITIONS OF PUNJAB

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ABSTRACT

A field study was conducted at different nitrogen rates on growth, yield and achene oil content of sunflower sown at different planting densities at Faisalabad, Punjab, Pakistan. Randomized complete block design with split plot arrangement was applied, having plants densities (8.33, 6.67 and 5.56 plants m^{-2}) in main plots and while various nitrogen levels (90, 120 and 150 kg ha^{-1}) in sub-plots. The plant densities and various nitrogen levels had a significant effect on leaf area index, crop growth rate, 1000-achene weight, head diameter, number of achenes $head^{-1}$,biological yield, oil quality, harvest index and achene yield of sunflower. The plants which were fertilized at 150 kg N ha^{-1} gaveabout 24% more achene yield as compared to 90 kg N ha^{-1}. More oil content was obtained in plots where nitrogen was applied at the rate of 90 kg ha^{-1}. It can be concluded that nitrogen application at the rate of 150 kg ha^{-1} with planting density (8.33 plants m^{-2}) produced highest achene yield.

Keywords: Sunflower, Nitrogen, Plant population, Head diameter, Achene yield, Pakistan.

INTRODUCTION

Due to ever increasing consumption of edible oil, however facing a severe shortage of edible oil in Pakistan. The local oil production is raised up to 0.612 million tons, which accounts for 23% of domestic necessity while the remaining 77% is met through imports. The sunflower has been recognized as a crop with high potentials that can successfully meet future oil requirements. Sunflower oil is a quite edible because it has soluble vitamins A, D, E and K and contains 60% poly unsaturated fatty acids as well as 16.25% oleic acid and 75.5% linoleic acid, having a positive effect on human health (Saleem et al., 2003). Although, this crop can be

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suitable in the existing cropping system of Pakistan but average yield is much lower than world's average due to poor soil fertility, lack of proper production technology, high costs of inputs, and marketing problems.

A suitable plant population is of prime importance in sunflower production. Weiss (2000) reported that the achene's yield of sunflower increases to a specific level by increasing the plant population. Plant density did not affect the radiation use efficiency but differences in total dry matter production due to variation in the leaf area index (Ferreira & Abreu, 2001). Plant population can be maintained by adjusting row to row or plant to plant spacing. Ishfaq et al. (2009) reported that sunflower sown on 60 cm apart rows produced significantly higher achene yield than45 cm. The increase in yield with narrow rows was largely related to increased higher leaf area index and maximum crop growth rate. Increasing plant population decreased stem and head diameter and enhanced plant height (Mojiri & Arzani, 2003). Achene yield and 1000-achene weight of sunflower increased with increasing row spacing (Diepenbrock et al., 2001) whereas, Nel et al. (2000) concluded that achene yield and achene weight of sunflower decreases by increasing the plant population. Higher plant populations produce lighter seeds, thinner stems, taller plants and more yield than lesser plant populations (Beg et al., 2007). Salehi et al. (2000) reported that increasing plant population of sunflower enhanced oil and achene yield and reached maximum at plant population of 6.67 plants m^{-2} with 25 cm plant spacing.

Nitrogen plays an important role in improving the growth, yield as well as quality of all crops (Ullah et al., 2010). The yield of sunflower increased by 19 to 40% in response to nitrogen (Zubillaga et al., 2002). Moreover, a higher rate of nitrogen increases photosynthetic processes, leaf area production; leaf area duration as well as net assimilation rate and ultimately contributing towards higher grain yield (Rafiqet al., 2010). Improvement and development of leaf area, crop growth rate and radiation interception are affected by the utilization of nitrogen (Nasim et al., 2012).

The higher yield resulted where nitrogen fertilizer rate was 180 kg ha^{-1} than other rates of nitrogen fertilizer (0, 60, 120, 240 kg ha^{-1}). Scheiner et al. (2002) reported that excess nitrogen fertilizer application in sunflower causes increases environmental risk, decreases the quality of achene and oil contents and also reduces the achene yield due to lodging of plants.

Therefore, the present study was conducted to evaluate the effect of different nitrogen rates on growth, grain yield and achene oil contents of sunflower planted at various planting densities under agro-ecological conditions of Faisalabad, Punjab, Pakistan.

MATERIALS AND METHODS

The experiment was conducted at Agronomic Research Area, University of Agriculture, Faisalabad (31^{o}.40" N, 73^{o}.11" E). The soil is sandy clay loam according to USDA classification (Anon., 1998).The analysis of soil was carried out before sowing the crop. Composite soil samples were collected from the experimental area at depth of 0-15 and 15-30 cm (Table 1).

The experiment was conducted during the spring season of 2012. The experiment was laid out in split plot arrangement having three replications. There were three planting populations (8.33, 6.67 and 5.56 plants m^{-2}) in main plot and three nitrogen levels (90, 120 and 150 kg ha^{-1}) in sub plot. To achieve plant population of 8.33, 6.67 and 5.56 plants m^{-2}; plant to plant distance was maintained at 20, 25 and 30 cm, respectively along with row spacing of 60 cm. After field preparation flat sowing was done with hand drill. The crop was sown on 1 March, 2012. After germination and seedling establishment, plants were thinned to one plant per hill. Crop was irrigated with canal water using surface irrigation method. Phosphorus and potash were applied @ 100 and 60 kg ha^{-1} respectively. Diamonium phosphate (DAP) and sulphate of potash were the source of phosphorus and potash respectively. Whole amount of phosphorus and potash was applied at sowing. First irrigation was applied just after planting of seeds and subsequent irrigations were applied on fortnightly basis up to flowering with amount of three acre inch. To control weeds, the plots were hoed twice. Following earthing up manuallyto protect it from lodging. Nitrogen fertilizer was applied in 3 splits in the form of urea. 1/3rd dose was applied at the time of seed bed preparation, 1/3rd at 7 days after sowing and remaining 1/3rd at third irrigation. All other agronomic practices uniform for all the treatments. The crop was harvested on 15th June, 2012.

A sample of five plants was selected in each plot fortnightly for measuring growth parameters such as leaf area index, total dry matter production and crop growth rate. Ten plants were selected for the determination of different yield attributes like plant height, head diameter, number of achenes $head^{-1}$, 1000-achene weight and achene yield at final harvest. The harvest index was calculated as the ratio of grain yield by biological yield. The oil contents were determined by soxhlet fat extraction method and oil yield was calculated by multiplying total achene yield with oil content.

The experimental data was statistically analyzed using the statistical computer software MSTAT-C.and least significance difference (LSD) test at $P \leq 0.05$ was used to compare the differences among treatments means.

RESULTS AND DISCUSSION

Leaf area index

The result showed that leaf area index (LAI) progressively increased and achieved its maximum value at 60 days after sowing (DAS) when anthesis started (Figure 1.). Thereafter LAI decreased in all treatments and reached its minimum at 80 DAS. The LAI increased with increase in nitrogen levels from 90 to 150 kg N ha^{-1}. The treatment where nitrogen was applied @ 150 kg ha^{-1} achieved maximum LAI (4.5) which was at par with 120 kg N ha^{-1} while minimum LAI (3.6) was observed at 90 kg ha^{-1}. Plants which were fertilized at 150 kg N ha^{-1} attained 24.6% more LAI than fertilized with 90 kg N ha^{-1}. More LAI ensure the higher photosynthetic rate, which further facilitate the higher dry matter accumulation. Similarly, more LAI could be due to significant developments in leaf expansion, for example, length and breadths of the leaves that might be dependent upon high nitrogen rates. The positive effect of nitrogen on LAI of sunflower hybrids has also been reported by Bange et al. (2000).

LAI increased linearly with increase in plant population from 5.56 to 8.33 plants m^{-2}. Maximum LAI (4.7) was recorded with planting density 8.33 plants m^{-2} and it was statistically similar at planting population of 6.67 plants m^{-2}. Plant population 5.56 plants m^{-2} produced minimum LAI (3.3). The relationship between LAI and achene yield was linear and positive, with value of (R^2 = 0.65) as shown in figure 3.

Total dry matter (kg ha^{-1})

Figure 2 indicated that the effect of nitrogen fertilizer was positive and linear in the production of total dry matter (TDM). Maximum TDM (11286 kg ha^{-1}) was observed at 150 kg N ha^{-1} followed by 120 kg N ha^{-1}. The nitrogen application @ 90 kg N ha^{-1} produced minimum TDM (10105 kg ha^{-1}). Plants which were fertilized at 150 kg N ha^{-1} attained 11.7% more TDM than 90 kg N ha^{-1}. The enhancement in TDM with increasing rate of nitrogen fertilizer could be due to better crop growth rate, which gave maximum photosynthates. The maximum TDM (11776 kg ha^{-1}) was observed from 8.33 plants per m^2 followed by 6.67 plants per m^2. The minimum TDM (9730 kg ha^{-1}) was recorded from plots where plant density was 5.56 plants per m^2. Higher TDM from 8.33 plants m^{-2} was due to additional dry matter accumulation and more achene yield. Thses results were in accordance with Ali et al. (2014) who reported that increasing plant density along with nitrogen increased TDM; however the interaction between nitrogen and plant densities was non-significant.

The possible reason for more TDM might be that 8.33 plants m^{-2} would be ideal for the plants to utilize the nutrients, light and moisture and had contributed towards the promotion of total dry matter accumulation with a significant difference. The relationship between TDM and achene yield was positive and linear with values of (R^2 = 0.98) as shown in figure 3.

Crop growth rate (g m^{-2} d^{-1})

Crop growth rate (CGR) expresses the rate of dry matter accumulation per unit area per day. Mean crop growth rate was highly significant ($P \leq 0.01$) at different nitrogen rates 90 kg N ha^{-1},120 kg N ha^{-1} and 150 kg N ha^{-1} with values of 12.0, 12.5 and 14.5 g m^{-2} d^{-1}, respectively as shown in figure 4. The results showed that CGR increased with each successive day. Nitrogen at the rate of 150 kg N ha^{-1} gave maximum CGR (13.4 g m^{-2} d^{-1}) may be attributed to more vegetative growth due to nitrogen application. Nasim et al. (2012) concluded that the nitrogen application had durable consequence on the improvement and increase of leaf area in terms of radiation interception.

Plant population 8.33 plants m^{-2}, 6.67 plants m^{-2} and 5.56 plants m^{-2} were highly significantly different with mean CGR values of 15.1, 13.3 and 10.6 (g m^{-2} d^{-1}) respectively. The 8.33 plants m^{-2} resulted 4% more crop growth rate as compared to 5.56 plants m^{-2} because 8.33 plants m^{-2} has more number of plants per unit area. The interaction effects of different nitrogen rates and plant population were found insignificant.

Plant height (cm)

The application of nitrogen @ 150 kg ha^{-1} produced maximum plant height (187.9 cm) whereas minimum plant height (180.7 cm) was recorded in at nitrogen level of 90 kg ha^{-1} (Table 2). Similar results were observed with increasing the rate of nitrogen fertilizer by Ishfaq et al. (2009). The maximum plant height (187.1 cm) was recorded with plant population was 8.33 plants m^{-2} while minimum plant height (180.8 cm) from5.56 plants m^{-2}. The reason of more plant height at narrow plant spacing might be due to better utilization of nutrients, light, moisture and more competition among plants as compared to more spaced plants. These results are conformity to Ali et al. (2011) who reported that with increasing plant density, the plant height increased mainly due to more supply of nutrient, light, moisture and air as compared to narrow spacing. The interaction between different levels of nitrogen and planting densities was non-significant.

Head diameter (cm)

Head size contributes substantially to achene yield because it influences both achene size and number of achenes per head of sunflower.

Head diameter was increased with increasing nitrogen levels from 90 to 150 kg ha^{-1}. The maximum head diameter (18.6 cm) was recorded with 150 kg N ha^{-1}but statistically at par with 120 kg N ha^{-1}while minimum head diameter (16.0 cm) from 90 Kg N ha^{-1}. These results were similar to the findings of Iqbal et al. (2008). They recorded maximum head diameter from treatment where N was applied @ 120 kg ha^{-1}.

Head diameter was decreased with increase in plant density. Maximum head diameter (19.1 cm) was obtained from 5.56 plants m^{-2} compare to 8.33 plants m^{-2} which gave minimum head diameter (16.3 cm). The possible reason for better plant growth is due to proper utilization of nutrients, light, moisture and less plant competition with planting densities of 5.56 plants m^{-2}. These results are in close agreement with the findings of Al-Thabet (2006) who reported that head diameter of sunflower crop was significantly increased with increase in space between plants. The interaction between different nitrogen levels and planting densities was non-significant.

Number of achenes per head

Results presented in table 2 exhibited that the number of achenes per head increased with increase from 90 to 150 kg N ha^{-1}. Nitrogen application @ 150 kg ha^{-1}

produced higher number of achenes (1106) per head which was statistically similar with 120 kg N ha^{-1}. While 90 kg ha^{-1} produced lowest achenes number per head (992.3). Nitrogen rate at 150 kg ha^{-1} attained 11.5% additional number of achenes per head as compared to that in 90 kg N ha^{-1}.

Number of achenes per head increased with decrease in plant densities from 8.33 to5.56 plants m^{-2}. The plan population 5.56 plants m^{-2} produced highest number of achenes per head (1167) followed by 6.67 plants m^{-2}. The reason was that head diameter was more in 5.56 plants m^{-2} so it produced more number of achenes per head. While minimum numbers of achenes (954.0) per head from 8.33 plants m^{-2}. Similar results were reported by Ali et al. (2011) they reported that with decreasing plant population the number of achenes per head of sunflower was increased. The interaction between different levels of nitrogen and planting densities was non-significant.

1000-achene weight (g)

The data in table 2 revealed that maximum 1000-achene weight (42.84 g) was recorded with 150 kg N ha^{-1} which was at par with 120 kg N ha^{-1} while Minimum 1000-achene weight (38.9 g) at 90 kg N ha^{-1}. The plants which were fertilized at 150 kg N ha^{-1} attained almost 10% more 1000-achene weight than 90 kg N ha^{-1}.The increase in growth characters and yield components with the increase in nitrogen levels might be due to the role of nitrogen in stimulating vegetative growth. These findings are in corroborates with the results of Haq et al. (2006). They noted that nitrogen application caused increase in achene weight of sunflower hybrids. The maximum value of 1000-achenes weight (43.2 g) was recorded with plant population of 5.56 plants m^{-2} statistically at par with 6.67 plants m^{-2}while minimum weight (39.7 g) was observed at 8.33 plants m^{-2}. The reason for higher 1000-achene weight could be due to less competition for light, moisture and nutrients under planting densities of 5.56 plants m^{-2}. These results are in line with the recommendations of Al-Thabet (2006). The interaction between nitrogen fertilizer and plant spacing was non-significant.

Achene yield (kg ha^{-1})

The final achenes yield per hectare is formulated by the accumulated effects of individual yield components. The maximum achene yield (2908 kg ha^{-1}) of sunflower was recorded at 150 kg N ha^{-1} whereas minimum achene yield (2343 kg ha^{-1}) at N 90 kg ha^{-1}as shown in table 3. The plants which were fertilized at 150 kg N ha^{-1} attained almost 24.1% more achene yield as compared to plants fertilized at 90 kg N ha^{-1}.These results are in line with Zubillaga et al. (2002).Maximum value of achene yield (2889 kg ha^{-1}) was observed in plots where plant density was 8.33 plants m^{-2} and minimum value of achene yield (2526 kg ha^{-1}) of 5.56 plants m^{-2}. The reason for more achene yield of sunflower might be due to more number of plants per hectare. Similar results were presented by Kazemeini et al. (2009). Interaction between varying nitrogen levels and plant spacing was non-significant.

Achene oil content (%)

Table 3 showed that plant densities had non-significant on oil contents. Oil percentage decreased with increase in nitrogen levels from 90 to 150 kg ha^{-1}. Maximum oil percentage (40.0%) was obtained in plots which were fertilized at 90 kg N ha^{-1}; whereas, minimum oil percentage (38.3%) was observed in plots where nitrogen was applied at 150 kg N ha^{-1}. The nitrogen application at 90 kg ha^{-1} produced almost 4.3% more oil contents than 150 kg N ha^{-1}. The interaction of nitrogen fertilizer level and plant densities was non-significant.

Harvest index (%)

Plant population did not significantly effect on harvest index. Nitrogen level at 120 kg ha^{-1} gave maximum harvest index (25.9%) but statistically at par with 150 kg N ha^{-1}. Minimum harvest index (23.3%) was observed at nitrogen rate of 90 kg ha^{-1}. Increases in HI with application of nitrogen at 90 kg ha^{-1} might be due to better crop growth rate, which gave better LAI and ultimately produced optimum biological yield. Previously Jin et al. (2010) reported similar type of approaches. Harvest index increased when plant density decreased from 8.33 to 5.56 plants m^{-2}. The lower plant population of 5.56 plants m^{-2} gave higher harvest index (25.9%) as compared to other planting densities, while minimum harvest index of 24.5% was observed with 8.33 plants m^{-2}. However, there was no difference in nitrogen fertilizer and planting densities regarding harvest index.

CONCLUSION

Nitrogen application at the rate of 150 kg $ha^{-1}$and planning densities of 8.33 plants m^{-2} gave higher achene yield as against with nitrogen rates and planting densities. More oil contents were obtained in plots which were fertilized at 90 kg N ha^{-1}. However, it recommended that sunflower should be fertilized at 120 kg N ha^{-1} along with planting density of 8.33 plants m^{-2} to achieve maximum benefits.

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Table 1. Physio-chemical analyses of the soil samples from Experimental Site

Determination	**Values**
A. Physical Properties	
Sand (%)	62.25
Silt (%)	16.25
Clay (%)	21.50
B. Chemical Properties	
pH	7.56
Organic Matter (%)	0.87
Total Nitrogen (%)	0.062
Available Phosphorus (ppm)	8.90
Available Potassium (ppm)	193

Table 2. Effect of different plant population and nitrogen levels on yield attributes of sunflower

Planting population	**Plant height (cm)**	**Head diameter (cm)**	**Number of achenes/head**	**1000 – achene weight (g)**
(83,333 plants ha^{-1})	187.0 a	16.3 c	954 c	39.7 b
(66,666 plants ha^{-1})	184.9 b	17.4 b	1067 b	41.5 ab
(55,555 plants ha^{-1})	180.8 c	19.1 a	1167 a	43.2 a
LSD (5%)	1.77	0.53	74.7	1.9
Nitrogen levels (kg ha^{-1})				
90	180.7 c	16.0 b	992 b	38.9 b
120	184.2 b	18.3 a	1090 a	42.6 a
150	187.9 a	18.6 a	1106 a	42.8 a
LSD (5%)	0.98	1.2	47.7	2.4

Table 3. Effect of different plant population and nitrogen levels on yield, oil content & HI of sunflower

Planting population	**Achene yield (kg ha^{-1})**	**Achene oil content (%)**	**Harvest index (%)**
(83,333 plants ha^{-1})	2889 a	38.9	24.5
(66,666 plants ha^{-1})	2665 b	39.0	24.5
(55,555 plants ha^{-1})	2526 b	38.9	26.0
LSD (5%)	191.5	NS	NS
Nitrogen levels (kg ha^{-1})			
90	3243 b	40.0 a	23.3 b
120	2829 a	38.6 b	25.9 a
150	2908 a	38.3 b	25.8 a
LSD (5%)	134.6	0.89	1.37

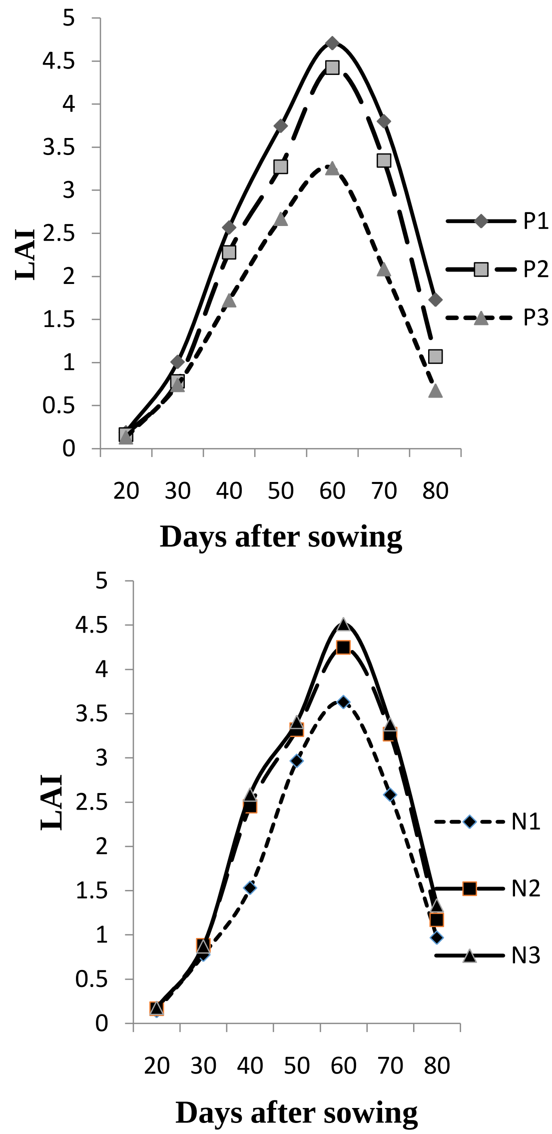


Figure 1. Effect of different planting densities & Nitrogen levels on leaf area index during the growth season

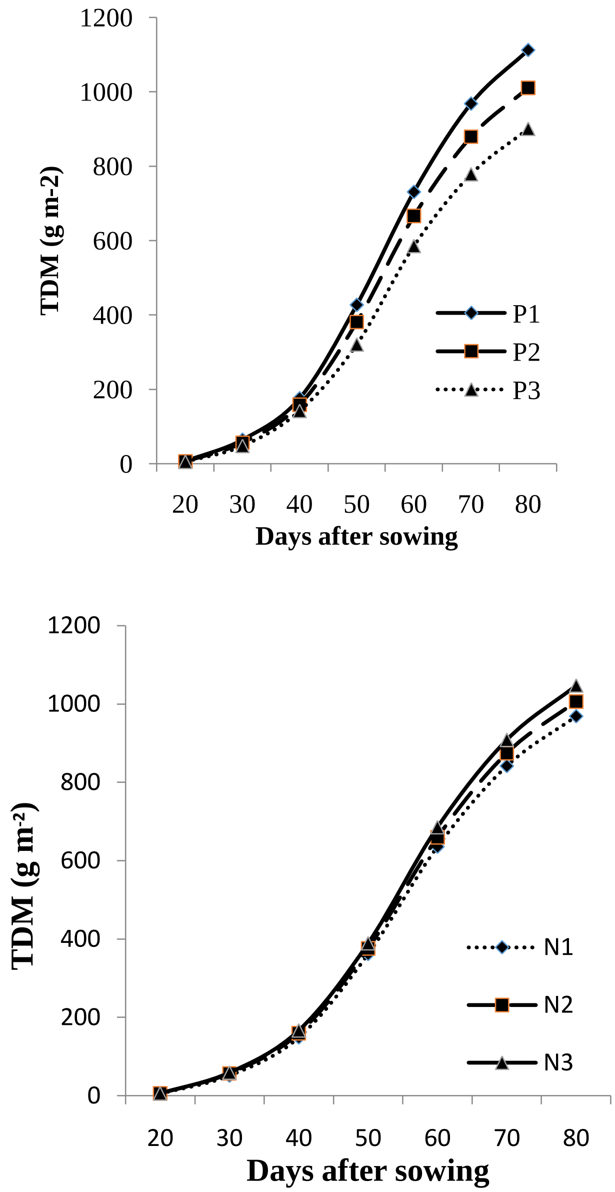
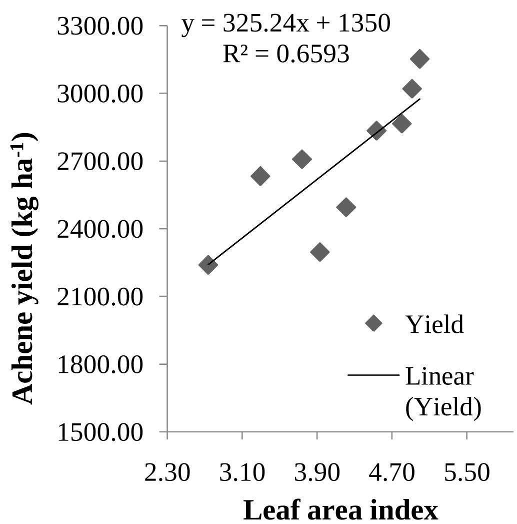


Figure 2. Effect of different planting density & nitrogen levels on total dry matter during the growth season



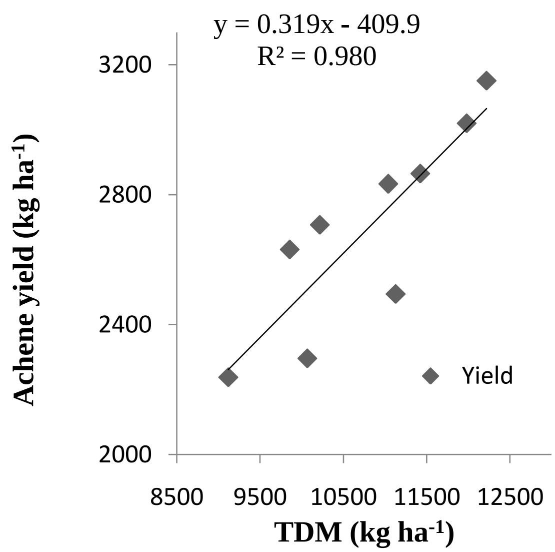
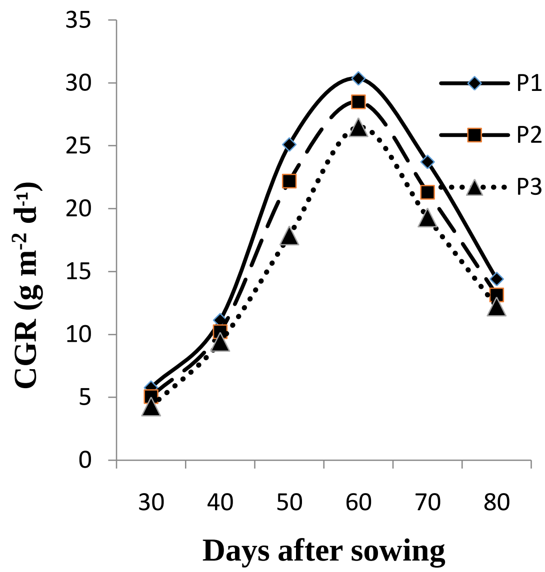


Figure 3. Relationship of achene yield (kg ha^{-1}) with LAI and TDM (kg ha^{-1})



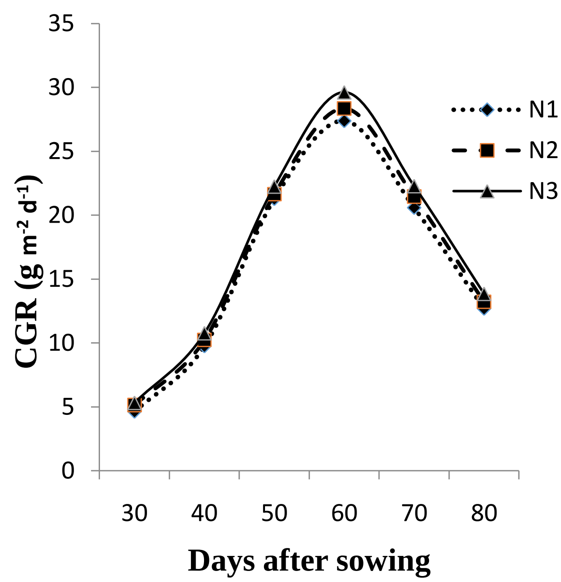


Figure 4. Effect of different plant population & nitrogen levels on crop growth rateduring the growth season