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Nitrogen Nutrition and Planting Density Effects on Sunflower Growth and Yield: A Review

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Abstract: Sunflower because of its quantity and quality of edible oil occupies an important position in the world among the new oil seed crops. To improve achene yield and quality of sunflower in our country different strategies have been adopted. One is to increase number of plants per unit area, which ultimately needs more nitrogen for its physiological and nutritional requirements. Normally, by increasing plant density decreases plant height, head diameter and 1000-achene weight. On the other hand, generally high rate of nitrogen application leads to more rapid leaf area development, prolongs life of foliage, increases leaf area duration after flowering and enhance on the whole crop assimilation, consequently contributing to increase in seed production. By the N application head diameter, 1000-seed weight, biological yield, seed yield per head, seed yield per plant were increased though harvest index and seed oil concentration were decreased. With the increase of nitrogen supply leaf gas exchange and shoot dry weight parameters improved but beyond that these decreased and optimum nitrogen concentrations were different among cultivars. Seed viability, seedling vigor and cool germination test performance, leaf area index, biomass production, seed weight and seed yield per unit area all were found to increase significantly due to the addition of the high N rate. Grain yield and photosynthesis active radiation absorption increase with increasing nitrogen levels and plant density. However, excess rates of nitrogen by enhancing vegetative growth of aerial parts, prolongs the periods to flowering and physiological maturity. High concentration of nitrogen did not affect specific leaf weight but resulted in more dry matter production per plant. With increase in N supply, RUE might also increase but in a lower order than LAI and IPAR. Nitrogen application appreciably enhanced interception of PAR and RUE of sunflower crop sown in irrigated areas. It is, therefore, concluded that while considering the optimum plant density in sunflower nitrogen should rates should also revised to harvest maximum achene and oil yield.

Key words: Sunflower, N application, plant density, nutritional and physiological significance

INTRODUCTION

Sunflower (*Helianthus annus* L.), because of its quantity and quality of edible oil occupies an important position in the world among the new oil seed crops. The yield of sunflower is controlled by several factors, including selection of suitable hybrids, proper production technology and management practices especially optimum plant population in the field, judiciously use of fertilizer, particularly nitrogen and social and marketing systems (Ishfaq *et al.*, 2009; Ali *et al.*, 2011). Under semi arid and arid conditions where soil moisture is a limiting factor, maintaining an optimum plant population is a key factor for increasing yield (Koutroubas *et al.*, 2008; Ali *et al.*, 2012).

Oil seed production in Pakistan is less due to certain problems, like, improper uses of fertilizers, low plant population per unit area, use of previous and fewer potential varieties, lack of knowledge of the producer about site specific production technology, unavailability and high prices of inputs, post harvest problems and inefficient marketing system (Gimenez *et al.*, 1994; Malik *et al.*, 2001; Shah *et al.*, 2005; Anwar-ul-Haq *et al.*, 2006; Arshad *et al.*, 2009; Zahoor *et al.*, 2010). The future prosperity and economic solidity of Pakistan principally depends on the quantum of material resources and their judicious exploitation and utilization. Thus, exploring the potential of newly developed hybrids through the exploitation of availability natural resources (with proper plant population and higher nitrogen supply, ultimately, resulting in higher growth, intercepted Photosynthetically Active Radiation (PAR) and yield components has been proposed as possible solutions for reducing the import bills and increasing the profits for the low income farmers of the irrigated arid and semi arid areas (Ahmad *et al.*, 2009; Zahoor *et al.*, 2010).

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Effect of planting densities: Plant spacing effects are greatly prominent in various crops including sunflower because there is no option of filling gaps between plants by tillering and branching. Thus an appropriate plant stand may help in harnessing the entire renewable resources in a supplementary and proficient approach toward high crop yields. Mojiri and Arzani (2003) demonstrated that with increasing plant population in field incremental and negative effects were recorded on plant height and head diameter, respectively. Seed yield was increased upto a plant population of 85000 plants ha^{-1} while beyond this had a depressing outcome on production. Xiao *et al.* (2006) demonstrated that the mean plant height increased with rising plant density (1, 4, 16 plants/m^2) and then decreased with further increase in plant density (64 plants/m^2). Higher plant density produce taller plants, lighter seeds and more yield than low plant population (Beg *et al.*, 2007; Ishfaq *et al.*, 2009). Kazemeini *et al.* (2009) conducted an experiment on sunflower by sowing crop at row spacing of 50 and 75 cm and noted the highest seed yield and oil percentage at 75 cm spacing.

Effect of nitrogen application: Nitrogen is an essential mineral nutrient for plant growth. High rate of nitrogen application leads to more rapid leaf area development, prolongs life of foliage, increases leaf area duration after flowering and enhance on the whole crop assimilation, consequently contributing to increase in seed production (Khaliq *et al.*, 2008; Khaliq *et al.*, 2009). Application of nitrogen noticeably improved growth, development and yield, while decreased in seed oil content percentage was observed. By the N application head diameter, 1000-seed weight, biological yield, seed yield per head, seed yield per plant were increased though harvest index and seed oil concentration were decreased (Kasem and El-Mesilhy, 1992). Malik *et al.* (2004) concluded that different combinations of NPK had highly significantly affected achene's yield and oil contents. Nasim *et al.* (2011) observed that with increasing nitrogen rates, there was addition in the biomass, yield and yield components, despite the fact that the oil contents were depressingly affected. Gao *et al.* (2012) concluded that high yield of integrated hybrids along with strategic management of crops, soil and nitrogen are crucial for achieving high yield. Tafteh and Sepaskhah (2012) reported that nitrogen is one of the main plant nutrients affecting plant growth and yield. Nitrogen application at the rate of 200 kg/ha is optimum in cereal and oil seed crops to obtain highest grain yield. Nitrogen was applied in different rates of 0, 30, 60, 90 and 120 kg/ha to sunflower cultivars EC 68414, Morden, APSH 11 and MSFH grown in the late kharif season on a sandy loam soil and concluded that seed yield increased with N application and was highest in EC 68414. Oil percentage was not significantly affected by N-application (Faizani *et al.*, 1990). Excess rates of nitrogen by enhancing vegetative growth of aerial parts, prolongs the periods to flowering and physiological maturity (Lang *et al.*, 1986; Somarin *et al.*, 2009; Mehdi *et al.*, 2010).

Different levels from 0 and 80 kg N/ha was applied in sunflower crop and at the highest rate of nitrogen (80 kg/ha) crop performance was excellent (Tiwari and Parihar, 1992). Sunflower cultivar EC 68415 grown at Hisar, Haryana in India at 4 fertility levels yielded two times higher yield with 60 kg N+30 kg P/ha or 80 kg N+40 kg P/ha than the yield obtained without N and P (Sarmah *et al.*, 1992). Growth, yield and yield components were notably affected by different rates of nitrogen (Rasul, 1992). Sunflower grown on deep black soil produced mean seed yield of 1.28, 1.75, 1.89 and 1.93 t/ha with 0, 40, 80 and 120 Kg N/ha, respectively (Hiray *et al.*, 1992). Optimum rates of nitrogen for cultivars BSH and Morden were 60 kg and 40 kg/ha, respectively (Hiremath *et al.*, 1990). By nitrogen application, seed yield per head, seed yield per plant was increased with increase in head diameter, 1000-seed weight, but harvest index and seed oil percentage were decreased (Kasem and El-Mesilhy, 1992). Sunflower Production could be enhanced by fertilizer application, chiefly nitrogen. All the metabolic routes which are based on protein, leads to increase in vegetative, reproductive growth and yield of the crop (Martinez *et al.*, 2010) are dependant upon the amount of nitrogen fertilization (Veerana and Steer, 2003).

Sunflower was grown with 40, 80 and 120 kg N/ha. Seed yield was highest with 80 kg N/ha (Viver and Chakor, 1994). It was found that the application of nitrogen @ 100 kg N/ha seems to be an appropriate and economical for sunflower (Arshad, 1994). Nitrogen rates from 200 to 800 g/m promoted growth with doubling interception (1.9) and RUE (2.1). Interception increased more (2.5) than did RUE (1.6) in the first stage of growth, up to 41 das. Leaf nitrogen concentration in the range of 1.0 to 2.8 N/m, maximum leaf photosynthesis increased from 10 to 40 µmol/m^2/s at high irradiance. The major part comprised approximate responses of partitioning of biomass, while only a small part (14%) of the observed response in RUE could be attributed to greater photosynthesis resulting from higher amount of N content and its distribution in the canopies (Gimenez *et al.*, 1994). In the subtropical environment under high N supply, production was higher because of lower-temperature regime extending the crop duration. The response of grain yield to application of nitrogen in the different experiments was linked with much larger effects on TDM production than on harvest index (Muchow and Sinclair, 1994).

Nitrogen plays an important role in photosynthesis and integral component of protein and is essential for enzymatic processes. The amount of N applied required depending on the crop and soil management systems used, relatively small amounts of available nitrogen at crop establishment and initial tiller development should be ensured. Supplementary N would then be applied at the end of tillering in most of crops (Walter *et al.*, 1995).

Seed yield was found to increase significantly by various N and P_2O_5 levels over control. Highest seed yield was obtained in plots treated with 125-125 kg NP/ha (Maqbool, 1992). Leaf area index, dry matter and seed production (kg/ha) increased extensively with increase in N levels from 0 to 100 kg N/ha. The interactions of N and plant population confounded the main effect of each factor on the growth and yield of sunflower. The use of 100 kg N/ha at 80000 plants/ha is therefore recommended for maximum yield of sunflower (Tenbe *et al.*, 1996).

In a field experiment the response of sunflower to 40, 80 and 120 kg N/ha was studied. It was observed that test weight, head weight and husk, seed ratio were influenced significantly with 80 kg N/ha over 40 kg/ha (Tomar *et al.*, 1997). Application of nitrogen @ 125 kg/ha produced large sized heads, more number of seeds per head, 1000 grain weight and achene yield as compared to nitrogen rates of 190 and 250 kg/ha (Ishaque, 1997). Sunflower responded positively to N with increased seed and oil yields and seed protein content. Application of 120 kg/ha nitrogen with 50 kg/ha phosphorus produced the highest response in seed yield (Maragatham and Chellamuthu, 2000). Nitrogen application @ 100, 150 and 200 kg/ha produced the grain yield of 16.8, 22.3, 35.4 q/ha and differed statistically. Highest number of filled seed/head (1024) was recorded with 200 kg/ha and lowest (787) with no fertilizer. An ongoing raise in quantity of filled seed was achieved with consecutive doses of nitrogen (Ghani *et al.*, 2000). Nel *et al.* (2000) applied three levels of nitrogen (20, 70 and 120) to sunflower and observed that seed yield increased on an average by 20% per 50 kg/ha. Rise in plant height and yield with nitrogen fertilization has also been reported by Abdel-Motogally and Osman (2010).

Nitrogen is an essential mineral nutrient for plant growth. It is a part of chlorophyll, enhances rate of photosynthesis, imparts green colour to the plants and ultimately increases vegetative growth. High rate of nitrogen application leads to more rapid leaf area development prolongs life of leaves; leaf area duration is improved after flowering and boost overall crop assimilation, thus contributing to increase in seed yield (Balasbramaniyan and palaniappan, 2001). It was observed that various levels of nitrogen significantly affected all the physiological parameters of sunflower, highest plant height, leaf area and head diameter were obtained from the plots where nitrogen was applied at the rate of 120 kg/ha (Iqbal *et al.*, 2008).

Nitrogen application enhanced the seed yield, however, reduction of seed oil content percentage was relatively small (2-5%) and was overcompensated by the seed yield increase at the approachable site (Javier *et al.*, 2002). Karam *et al.* (2007) concluded that from groundwater nitrogen inputs was considerable as a module of the soil nitrogen balance and improved the potential of N loss with leaching as a source of point pollution. To achieve a 100% yield maximum nitrogen and phosphorus combination (181 kg/ha at P40) give best results (Zubillaga *et al.*, 2002).

Sunflower growth and yield components (i.e., plant height, leaf area per plant number of filled achenes per head, head diameter, thousand achene weight, biological and achene yields) were observed significantly higher with the treatment 150 kg N/ha (Ali *et al.*, 2004). Three different levels of N, P and K fertilizer were studied and it was concluded that increasing NPK levels increased the yield and yield components but decreased the oil component (Malik *et al.*, 2004). With the increase of nitrogen supply leaf gas exchange and shoot dry weight parameters improved but beyond that these decreased and optimum nitrogen concentrations were different among cultivars (Shangguan *et al.*, 2004). High concentration of nitrogen did not affect specific leaf weight but resulted in more dry matter production per plant. The photosynthetic CO_2 assimilation (A) of the target leaves was remarkably improved by higher nitrogen nutrition (Cechin and Fumis, 2004). Nitrogen levels significantly affected total quantity of seeds/head, 1000-grain weight, seed and oil yield. Nitrogen at the rate of 60 kg/ha treatment gave highest seed and oil yield (Killi, 2004). Ozer *et al.* (2004) conducted 2-year study under irrigated conditiond by sowing two oilseed sunflower hybrids (AS-508 and super-25). In this study, nitrogen fertilizer significantly influenced all growth and yield parameters, positive and linear response of yield were noted to nitrogen rates. The N level of 120 kg/ha was found adequate under irrigated conditions for sunflower production in this region.

Total dry matter (TDM) production varied with N rates and irrigation timings. The maximum biomass was recorded with 200 kg N/ha. The higher N application level resulted in reduction in harvest index (Khaliq and Cheema, 2005). The total root length (TR) enlarged as nitrate levels increases. At low N supply (0.04-2 mM) there was a major constructive correlations with the root dry weight, TR and PR (Primary roots) but to some extent only LR was correlated to N accumulation at high N supply (4 m M). It is concluded that, in N scarce site, a larger root system that resulted mainly from the longer primary roots contributed to the efficient N accumulation and longer lateral roots are the main factor contributed to N accumulation at sufficient N supply (Wang *et al.*, 2004). Nitrogen fertilization rates showed a considerable response in grain production and other measured parameters. In conclusion, for yield the significant relationship between N use efficiency and uptake show the significance of N nutrition in sunflowers, while the negative correlation between yield and oil content confirms that elevated grain production is coupled with lower oil content (Montemurro and Giorgio, 2005). Nitrogen level 185 kg/ha in split application was found sufficient to obtain highest corn yield and in most instances 125 kg/ha was adequate. Nitrates leaching to ground water on the sandy-textured soils will be minimized only when irrigation inputs and fertilizer do not exceed crop requirements and N fertilizer is applied to more closely match crop demand (Gehl *et al.*, 2005). Application of nitrogen has a key role in maintaining maximum grain yields; however, a number of other factors limit production even when N fertility is optimal (Derby *et al.*, 2005).

Nitrogen element noticeably improved growth and yield, although resulted in pointed decline in grain oil content at 200 kg/ha produced the utmost seed yield/ha, while the maximum oil yield/ha was recorded with application of 150 kg N/ha. Plant spacing of 25 cm and 200 kg N/ha for seed and oil yields were recommended (Al-Thabet, 2006). Under two nitrogen regimes, control where nitrogen was not given and other one where 90 kg N/ha was applied, radiation use efficiency was reduced to a greater extent where nitrogen level was zero. RUE (Radiation Use Efficiency) increased at increasing N application level in intensive northern growing conditions while it varied seasonally (Murrinen and Peltonen, 2006).

Nitrogen application (120 kg/ha) in combined form had been found to maintain the highest concentrations of N, P, Mg^{2+} and Ca^{2+} along with reduced concentrations of Na^{+}, Cl^{-} and SO_4^{2}. However, reverse was true with ammoniacal form of nitrogen (Nathawat *et al.*, 2007). At N-fertlization rates of 9 kg/ha (ZN), 40 kg/ha (LN), 60 kg/ha (MN) and 90 kg/ha (HN) both dry matter and grain yields were increased by N-fertlization significantly, affected the soil total N and C/N ratio at lower depth (0.15-0.30 m) (Habtegebrial *et al.*, 2007). The application of 150-50 N P Kg/ha is sufficient for satisfactory yield and qualitative characters of cotton and the use of inorganic nitrogenous fertilizers could be minimized by succession of legume crop in the crop sequence (Kumbhar *et al.*, 2008). There was 12 and 16% increase in grain yield in Waha with N fertilization of 150 and 200 kg/ha, respectively, as compared to 100 kg/ha N fertilization (Karam *et al.*, 2007).

All the phonological characteristics were considerably affected by time and rate of nitrogen application. Leaf number/plant and seed number/ear are significantly affected by different levels and split application of nitrogen. This study suggested that production can be maximized through high N split application (Amanullah *et al.*, 2009). In response to nitrogen and seed density many traits responded differentially across environments. However, most of the investigated traits were affected significantly by nitrogen and total nitrogen fertilizer desired to maximize sunflower production was estimated to be 68 kg/ha (Elfadl *et al.*, 2009). Seed viability, seedling vigor and cool germination test performance, leaf area index, biomass production, seed weight and seed yield per unit area all were found to increase significantly due to the addition of the high N rate (Sawan *et al.*, 2001). Differences in sunflower achene yield, variation in biomass and harvest index were related similarly to different levels of N supply. With decreasing N supply the decrease in biomass production was related with reduction in both radiation interception and radiation use efficiency (RUE). Decreased interception and reduced RUE was due to effects of N supply on reducing canopy leaf area and decreased SLN (specific leaf N), respectively (Massignam *et al.*, 2009). Sunflower hybrid crop was fertilized by N application rate (0, 67, 134 and 202 kg/ha). The total saturated fatty acid and oil content were significantly affected by N rate. Different N levels may significantly modify fatty acid composition and oil content of sunflower, suggesting that these could be used as management tools for decreased total saturated fatty acid and increased oil content (Zheljazkov *et al.*, 2009). It was shown that high levels of N fertilization led to significantly ($p<0.05$) more PR than non fertilization (Seassau *et al.*, 2010).

Nitrogen in relation to crop growth: Growth and development of crop plants are a combination of many actions at different levels, from biophysical and biochemical to tissue and organ levels. Different ecological variables specifically temperature affects crop growth and developmen and is measured as a main determinant for regulation of various phenomenons (Ritchie and Ne Smith, 1991). An increment in nitrogen level, there is also increase in the growth and development and photosynthesis rate of the crop (Fayyaz-Ul-Hassan, 2005). A small number of reports are presented on the impact of nitrogen application on the phasic improvement of sunflower. Rate of development and growth of both vegetative (leaves) and reproductive (florets and seed) organs are very much affected by deficiency of nitrogen element. In early stages of growth especially at vegetative phase, scarcity of nitrogen causes decrease in leaves number and retards the growth of the leave resulting in sluggish leaf area index development and reduced interception of radiation (Hocking and Steer, 1983, 1995).

To speed up all protein based metabolic processes, accountable for rapid development in generative and vegetative growth and higher production ample supply of nitrogen is essential (Lawler, 2002; Khaliq, 2008;

Nasim, 2010). It has been confirmed in all sorts of trials that by enhancing the provision of nitrogen fertilizer, advancement in growth and photosynthesis also existed. Deficiency of N lowered the rate of photosynthesis because of reduction in individual leaf expansion and leaf area which got less light interception (Toth *et al.*, 2002). Leaf nitrogen content of leaf elevated and exhibts a well-built alliance between photosynthesis and leaf nitrogen content of many C_4 (photosynthetic ally active) and C_3 (less photo synthetically active) Species when nitrogen availability is sufficient (Connor *et al.*, 1993). In leaf chloroplasts entire leaf nitrogen contents (upto 75%) are present and most of these are utilized only in Ribulose Biphonsphate Carboxylase. Consequently, under nitrogen deficiency, lesser rates of photosynthesis are often recognized to lessen green pigments and performance of Rubisco enzyme (Fredeen *et al.*, 1991; Toth *et al.*, 2002). As compared with no nitrogen application photosynthetic activity and chlorophy ll contents of sunflower plant improved and enhanced leaf area under application of higher dose of N (160 kg/ha) (Ozer *et al.*, 2004). Maximum total dry matter (shoot) synthesis by the plant was improved with application of higher N, chiefly in early stages of growth (Cechin and Fumus, 2004). This difference in TDM was mainly credited to the impact of nitrogen on leaf production and on individual leaf dry matter. Nitrogen application from 30 to 60 kg/ha enhanced LAI and TDMproduction (Singh *et al.*, 2005).

Nitrogen Nutrition of Sunflower: Nitrogen element has a vital position in spurring the vegetative cover of the sunflower plants. Under variable nutrient availabilities differential responses of sunflower crop plant occur (Connor and Hall, 1997). Nitrogen fertilization Management is of main importance for the reason that many environmental as well as yield factors affect sunflower N requirement. Because of N deficiency vegetative as well as generative growth of plant reduces and premature senescence also occurs, as a result diminishing production (Narwal and Malik, 1985; Khokani *et al.*, 1993; Legha and Giri, 1999; Tomar *et al.*, 1997). The hazard of disease and lodging increases, it could worsen soil and surface water pollution due to excess of N application, with a consequential reduction in oil content also. In fileld the nitrogen use efficiency is low down (Ahmad *et al.*, 2001). In plants among essential mineral nutrient that affects plant composition nitrogen is the chief one and excessive use of that one raises all nitrogenous compounds. With increasing levels of N application soluble amino compounds contents boost additional promptly as compared to proteins (Mengal and Kirkby, 1982).

Nitrogen in relation to yield components: Effect of N application on agronomic traits, yield and yield components of sunflower (plant height, crop growth rate, leaf area index, head diameter, number of achenes/head, 1000 achenes weight and achene yield) was studied by many researchers around the globe and has been well documented.
Highest AY of sunflower was noted by application of 75 to 100 kg N/ha and then decreased with 120 kg N/ha was reported by several authors (Andhlae and Kalbhor, 1980; Singh, 2007) whereas; 80-85 kg N/ha was the most advantageous rate (Smiderle *et al.*, 2005). Ali *et al.* (2004) described that 150 kg N/ha gave the uppermost grain yield (992 t/ha) whereas 200 kg/ha N fertilization did not specify considerable raise over the former rate. Ogunremi (1986) accomplished that increasing N above 90 kg/ha decreased percentage of filled seeds and retarded achene and oil yilds drastically.
Positive response of agronomic traits to application of nitrogen may be the reason of significant and linear response of N on sunflower seed yield. Head diameter is of prime importance for yield determination among different yield components. As N level is increased, the head diameter also increased (Ozer *et al.*, 2004). Singh (2007) concluded that weight of seeds increased up to 80 kg N/ha and then a decline was observed at 120 kg N/ha. Several other researchers (Poonia, 2000; Ozer *et al.*, 2004; Ahmad *et al.*, 2005) observed a progressive and reliable raise in achene weight with addition up to 160 kg N/ha.
Number of achenes/head also positively associated with size or diameter of head and eventually contributing towards final grain yield. Advantaged achene yields intended for higher N treatments are connected by means of more achene number/head (Zubillaga *et al.*, 2002). The establishment of grain number around seed formation stage is dependent on the translocation of assimilates to some extent (Andrade, 1995). Nawaz *et al.* (2001), Al-Thabet (2006) and Singh (2007) also pointed out that increasing rates of nitrogen enhanced the achene numbers.

Nitrogen in relation to achene-oil quality: Negative impact of nitrogen on seed oil concentration was reported by a number of researchers (Scheiner *et al.*, 2002; Ali *et al.*, 2004; Ozer *et al.*, 2004; Al-Thabet, 2006). The considerable depressing correlation between seed oil content and higher rates of nitrogen could be probably attributed to the sugar translocation effecting oil synthesis (Salisbury and Ross, 1994). Correspondingly, alternating enzymes imbalance could also contribute in this reduction (Hussein *et al.*, 1980; Steer *et al.*, 1986). Kutcher *et al.* (2005) attributed such type of negative relationship to the diluting outcome of greater seed yield at more N fertilization and the opposite relationship between protein and oil content. Jackson (2000) observed that nitrogen fertilization resulted in prolonged physiological maturity period of crop following in higher proportion of green seed but the seed were poorly filled. Rich supply of nitrogen enhances protein precursors that are abundant in N and there is strong affinity of photo-synthetase to be utilized for protein formation and lesser of these are available for fat synthesis (Holmes, 1980).

Higher nitrogen supply increases the amount of seed oil yield, whereas depresses seed oil contents (Steer *et al.*, 1985; Chkerol Hosseini, 2006; Asghari, 2006) and this is because of dilution of oil in heavier seeds produced under more N and that was also proved true from the results presented by Khaliq (2004), that lesser N concentration does not offset the advantage that large N supported the seed weight. The findings of Ozer *et al.* (2004) also supported the significant of increasing nitrogen rates for increasing oil yield. In fact, the response was coupled directly with the response of seed yield to applied N rates. Singh *et al.* (2005) recorded an increase in total dry matter and oil yield with nitrogen applied at 30 and 60 kg/ha, likewise, Poonia (2003) observed the rise in oil yield upto 80 kg N/ha and was possibly because of increased seed yield being the function of oil content and seed yield. He further reported converse relationship between oil and protein contents and, the protein contents in seed increased upto 120 kg N/ha. Munir *et al.* (2007) studied the effect of integration of crop manuring as well as nitrogen application on quality of spring planted sunflower. The positive impact of increasing nitrogen rates was recorded as the treatments with 100 kg N/ha gained 15.39% protein contents and 11.5% in the control. Khaliq (2004) also stated such significant effect and found 12.08, 14.55 and 16.21% achene protein concentration with 0,100 and 200 kg N/ha, respectively, Ozer (2004) reported 9% increase in protein contents with 120 kg N/ha as compared to control. Ghani *et al.* (2000) also supported these findings that by increasing N application in sunflower will increase seed protein content.

In canola seed, protein contents improved progressively with increase in N levels and the highest protein content of 23 % was noted at the highest rate of 80 kg N/ha (Ahmad *et al.*, 2007). These results also confirmed the findings of Malhi and Leach (2000) and Kutcher *et al.* (2005). The more protein content at high rate of N may be because of negative correlation between seed oil and protein content (Hao *et al.*, 2004). The physiological reason for this negative relationship may be that the carbohydrate content of protein is lower than that of oils (Lambers and Poorter, 1992).

The incorporation and buildup of nutrients into callus cells and seeds depend not only upon genotype, but more or less upon the presence of that nutrient element. Many selection and breeding struggles throughout the world produced sunflower hybrids with improved monounsaturated FA composition; however, some of these hybrids had comparatively lesser oil content than that of traditional sunflower cultivars and hybrids. Agricultural factors that may raise oil content of sunflower are definitely of interest to producers, because of the fact that current sunflower prices at crushing plants are determined based on oil content (National Sunflower Association, 2009).

This review suggests that for realizing good harvest of sunflower hybrids, it is desirable that requirements for N nutrition be determined properly. Similarly the growth analysis of sunflower hybrids belonging to different maturity groups under varying planting densities are to be quantified in terms of intercepted radiation under local environments. This will optimize the development of packages of production practices that suit to different growers.

Nitrogen and planting density in relation to growth and light interception: Light interception is a major contributor to total dry matter accumulation of crop plants. Kiniry *et al.* (1989) reported that the amount of dry matter produced was proportional to the intercepted PAR and noted that 3.5 g above ground dry matter was produced in sunflower by the utilization of 1 MJ of PAR radiation interception and growth of sunflower RUE of 1.5-1.7 g/MJ was noted with the use of 80 kg N/ha (Watiki *et al.*, 1993). Sunflower extinction coefficient (k) during vegetative growth was within the range of recently published values (0.49±0.03) with no clear pattern of differences in k among years. Seasonal changes in interception of photo-synthetically active radiation (PAR) were parallel across all but one year. They further estimated RUE by two methods i.e., 3.74 (±0.20) g/MJ and 3.84 (±0.08) g/MJ and concluded that during grain filling RUE does not decline. They further reported that models they rely on RUE for biomass accumulation should use an RUE of 3.8 g/MJ PAR for predicting optimum yields without growth limitations (Lindquist *et al.*, 2005). The RUE is a chief crop parameter widely used in crop simulation models, derived as the slope of the relationship linking crop carbon gain to cumulative intercepted solar radiation. Deviation from linearity was observed after anthesis, due to higher carbon cost in yielding oil seeds in sunflower. No conclusion could be drawn for post-anthesis chickpea due to the interruption of the experiment caused by a thunderstorm. Overall results showed a great variability in ε values, independently of classes of species (C_3 and C_4), crops and nitrogen treatments. This shows that the robustness of ε to predict biomass productivity in crop simulation models is constrained. Attempt to normalize by vapour pressure deficit (D), for reducing its variability due to climate and overlaps between crops failed (Steduto and Albrizio, 2005).

Canopy development, light interception and radiation use efficiency: Being integral entities in plant enzymatic structures and reserve proteins in grain, nitrogen is identified as essential nutrient element for plants. Sinclair and Muchow (1999) demonstrated that the rate and extent at which dry matter accumulates by the crop is dependent on ability of the crop canopy to intercept incident photo synthetically active radiation (PAR) as well as radiation use efficiency (the effectiveness with which this radiation can be converted into new biomass). The important determinants of crop yields are extent of dry matter accumulation and its partitioning within the plant. Enough evidence is documented to establish that one or both of physiological mechanisms for biomass production may be altered by genotype, temperature or water availability. Genotype, temperature or water availability may be helpful to alter nitrogen deficiency (Calderini *et al.*, 1999; Jamieson *et al.*, 1995). Interception of incoming photo-synthetically active radiation and radiation use efficiency may be affected by nitrogen deficiency (Caviglia and Sadras, 2001; Rodriguez *et al.*, 2000). In crops grown under nutritional deficiency canopy architecture is less influenced than LAI because it is a primary determinant of the light extinction coefficient (K) (Hasegawa and Horrie, 1996).

Rapid change in the expansion of leaves may be affected more due to environmental stress than the photosynthetic capacity of the crop (Fitter and Hay, 2002), a reduction in leaf area index and intercepted photo synthetically active radiation occur in crop grown under nitrogen deficiency. Net CO_2 assimilation affects the utilization efficiency of radiation (Loomis and Amthor, 1999) and this process (CO_2 assimilation) depends upon availability of N, because it increases the RubisCo content in leaves (Sinclair and Horie, 1989). Hence, with increase in N supply, radiation use efficiency might also increase but in a lower order than LAI and IPAR (Integrated Photosyntheticall Active Radiation). Nitrogen application appreciably enhanced interception of PAR (Khaliq, 2004) and RUE of sunflower crop sown in irrigated areas.

Planting densities may be helpful to optimize fully intercepted available light required for a crop (Ball *et al.*, 2000). By the choice of cultivars of desired maturity, the duration of light interception by the crop may also be managed (Purcell *et al.*, 2002). Leaf area index (LAI), light interception (LI) and light interception efficiency (LIE) varies greatly at different developmental stages (Board and Harville, 1992). Among these parameters rapid and higher LAIs during vegetative and early reproductive development were the leading features liable for better light interception in contracted rows and were identified as selection criteria for cultivar genotype performance in more planting density at late planting.

A plateau of sunflower yield was observed when 85% threshold of radiation interception at flowering stage was achieved (Mercau *et al.*, 2001). Selection of hybrids of short growing cycle and short stature, very early sowing, defoliation and reduction in leaf expansion might be the reason due to which the crops may not be able to achieve full interception of radiation (Sadras *et al.*, 2000) and other factors, as water or nutrient deficits at vegetative stages (Trapani *et al.*, 1994; Sadras and Trapani, 1999). Ferreira and Abreu (2001) reported that at the densities of 11.4 (D_1) and 4 (D_2) plants/m^2 leaf number, canopy light extinction coefficient and the radiation use efficiency did not vary while crop dry matter production and solar radiation interception were smaller in D_2 than D_1 owing to greater leaf area index in D_1 in sunflower (Ferreira and Abreu, 2001). An increase in leaf area and aboveground dry matter per plant was observed in lower density (D_2).

Biomass production and harvest index of crop significantly influenced by accumulated intercepted radiation during grain filling period and both of these depended on the duration of grain filling and green leaf area (Vega and Hall, 2002). Grain yield and photosynthesis active radiation (PAR) absorption increase with increasing nitrogen levels and plant density (Dahmardeh, 2011). Bange *et al.* (1997) also described that dry matter accumulation was greatly affected by accumulated intercepted radiation rather than by radiation use efficiency. Weight per seed and oil concentration in sunflower could be badly affected as a result of decrease in intercepted photo-synthetically active radiation (PAR) for the period of seed filling (Aguirrezabal *et al.*, 2003). Schneiter and Miller (1981) also recorded that weight per seed was strongly linked with intercepted photo-synthetically active radiation from the closing stages of flowering to maturity stage of the crop.

Abbreviations: LAI (Leaf Area Index), RUE (Radiation Use Efficiency), PAR (Photo synthetically Active Radiation), IPAR (Integrated Photo synthetically Active Radiation), LI (Light Interception), LIE (Light Interception Efficiency).

Conclusion: Increasing plant density no doubt increases final achene yield but if it is combined with optimum level of nitrogen. It is, therefore, concluded that while considering the optimum plant density in sunflower nitrogen should rates should also be revised to harvest maximum achene and oil yield.

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