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Review Paper

Optimum Nitrogen Consumption in Maize at Different Moisture Regime (A Key to Enhance Corn Productivity) and Estimation of Yield Reduction under Nitrogen Limitation Conditions

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RESEARCH ARTICLE

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ABSTRACT
Nitrogen (N) is a key constituent of all living cells and is essential for the growth and development of plants .The phenological stages of growth and development are delayed due to nitrogen deficiency. The results of the research have shown that nitrogen deficiency causes a delay in the emergence of leaves. Increasing nitrogen consumption in terms of positive effect on the leaf area index and its durability creates a strong and sufficient physiological source to supply the necessary materials for the growth of vegetative parts such as stems. Nitrogen fertilizer is one of the important agricultural factors that has significant effects on growth indices, so that with the proper use of this fertilizer, a balanced combination of growth indices can be achieved in plant canopy and increase the grain yield. Due to the fact that most of the growth indices are directly or indirectly dependent on the leaf area index, changing this index by changing the amount of nitrogen consumption is one of the most practical ways to increase yield. Several studies have confirmed the positive effect of nitrogen on increasing the grain yield, the number of seeds per ear and the weight of the seeds in different corn hybrids. N fertilizer is the second largest requirement after water in crop production, and N is the most common yield-limiting nutrient deficiency. This element is absorbed by plants from the soil. Therefore, providing enough usable nitrogen in the soil for optimal plant growth is of particular importance. The low N use of the crop indicates that uptake is inefficient or higher than the plant's requirement. The optimal amount of nitrogen consumption depends on various factors such as water supply in the soil, density and the variety used. For example, increasing the water supply in the soil increases the yield of crops in response to nitrogen consumption, especially if the amount of fertilizer consumption is high. In this research, the relationship between the available water of the corn plant and the amount of nitrogen consumption has been investigated in order to achieve solutions to increase the efficiency of input consumption and reduce costs in different humidity conditions with optimal nitrogen consumption.

KEYWORDS: *Crop production, Fertilizer, Growth indices, Nutrition, Water stress.*

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1. BACKGROUND

The dramatic increase in population, the increasing need for food and the inadequacy of food resources have faced the problem of hunger and malnutrition in a large part of the world's people. The way to deal with this phenomenon is the optimal use of resources, facilities and the development of cultivation of high yielding products. Among the products that provide food resources, corn is one of the promising products to deal with this phenomenon due to its special characteristics, which has been cultivated on a large scale. Increasing public and specialized awareness is one of the things that can be effective in the correct management of the farm and as a result increase the production of this product. Maize is one of the oldest crops used for human, animal and especially poultry nutrition, which according to the FAO report in recent years ranks first among crops in the world in terms of production and in terms of cultivated area has taken the third place after wheat and barley. Corn word production last year (2022) was 1,216.87 million tons. This year's 1,161.86 estimated million tons could represent a decrease of 55.00 million tons or 4.52% in corn production around the globe. Corn cultivation in the world has found a close match with the arid belt due to the special characteristics of this plant in terms of being tetracarbonate (C4) and especially heat tolerance. The arid and semi-arid areas located in the arid belt are able to provide all the ideal conditions to produce high yield of this plant, except for sufficient humidity (Lak *et al*., 2006). Paying attention to increasing the skills of farmers and applying science and technology to increase plant yield per unit area and reduce production costs are among the things that should be prioritized in increasing grain corn production. Despite the fact that most of the increase and improvement of corn yield in recent years has been due to the use of improved cultivars, but in parallel with that, agronomic programs such as choosing the appropriate density, using chemical fertilizers and controlling weeds have also been effective in increasing corn yield. The results of the investigations show that more than 50% of the increase in food production is due to the use of chemical fertilizers, among which the share of nitrogen fertilizers is high compared to other fertilizers, but unfortunately, the efficiency of using nitrogen fertilizers is low (Raun and Johnson, 1999; Antep, 1997; Anas *et al.,* 2020). Nitrogen is the first element whose deficiency is raised in arid and semi arid regions (Marschner, 1995), because in these regions the amount of organic matter, which is the main source of nitrogen storage, for many reasons, including high temperature, low average consumption animal manures and green manures, rainfall is low and little. Most of the lands of the world are considered as arid and semi-arid areas. If nitrogen is available in sufficient quantity to the corn plant, it will cause its rapid growth. Nitrogen deficiency causes the growth of aerial organs to stop, especially seeds. Nitrogen deficiency has a negative effect on the production factors, the number of ears, the number of rows per ear, the number of seeds per ear and grain size are all influenced by nitrogen in successive stages of corn growth (Nourmohamadi *et al*., 2010).

2. OBJECTIVES

Current study was done to assess response of corn crop production affected to water stress and nitrogen limitation conditions.

3. EVIDENCE ACQUISITION

Current research was conducted according evaluate results of valid researcher.

4. RESULT AND DISCUSSION

Continuous and long-term nitrogen deficiency reduces grain yield even up to 70% compared to the conditions where sufficient nitrogen is available to the plant. On the other hand, using nitrogen more than what is necessary for the production of the crop may cause nitrate accumulation under the root zone and increase the risk of nitrate leaching. Hanway (1966) reported that the main effect of nitrogen in increasing the yield was by increasing the number of seeds per ear, and the weight of the seeds also increased due to the increase in nitrogen consumption. Lak *et al*. (2006) reported that with the increase in nitrogen consumption, the leaf area increased and as a result, the amount of absorption and the efficiency of light use by plant canopy increased. The combination of these factors increased the growth rate of the product and ultimately improved the grain yield (Fig. 1).

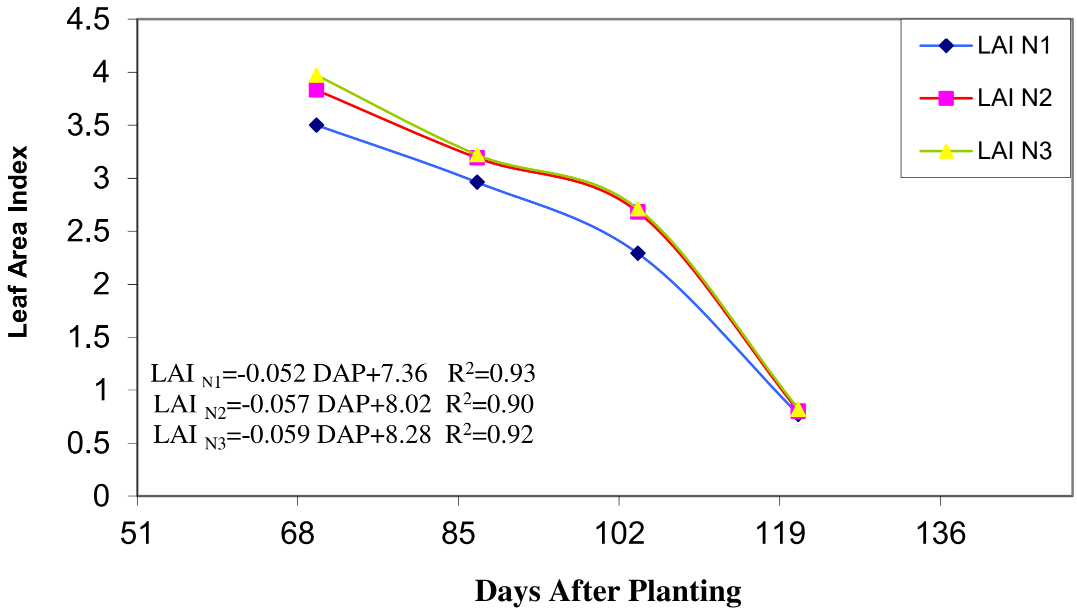

Fig.1. Response of variation of leaf area index to use different level of nitrogen at silking stage

Evans (1977) also believes that the number of seeds is one of the main components in the corn grain yield and the effect of nitrogen fertilizer on the number of seeds is positive. Uhart and Andrade (1995) and Ran *et al*. (2016) stated that nitrogen deficiency reduced seed yield by reducing number and weight of seeds, as a result of nitrogen deficiency, seed weight decreased from 9% to 25%, and grain yield also decreased between 14 and 80% compared to the control plants, the reason for the loss of seeds may be infertility, increased abortion or their non-development. Brandoua and Below (1992) found that nitrogen deficiency causes a significant decrease in number of seeds per ear and grain yield, the highest amount of nitrogen absorption by the corn plant takes place in the stage of emergence of male and female organs. Plant access to available nitrogen and its absorption is affected by factors such as water availability, plant density, etc (Burman *et al*, 1962). Reidenbach and Horst (1997) and Li *et al*. (2020) in corn observed a positive and significant relationship between water absorption and nitrogen absorption during life cycle of plant and reported that with increasing age of plant, the dependence of nitrogen absorption on water absorption increased. Lak (2013) reported on corn plants, use of large amounts of fertilizer in favorable irrigation conditions significantly increased grain yield, while in severe drought stress, use of large amounts of fertilizer did not significantly increase seed yield (Table 1). Dongliang *et al*. (2020) stated that coordinating supply levels of water and N is a useful approach to improve crop production and crop water productivity. Many experiments have been conducted regarding amount of nitrogen use in different humidity conditions. According to scientists, improper management of irrigation and nitrogen are main factors that reduce corn yield (Norwood, 2000; Wienhold *et al*., 1995).

Table 1. Mean comparison interaction effect of treatment on seed yield

Treatment (I*N)	Seed yield ($gr.m^{-2}$)
I_1N_1	932.4b
I_1N_2	1077.8a
I_1N_3	1140.5a
I_2N_1	800.3c
I_2N_2	927.0b
I_2N_3	967.3
I_3N_1	667.7d
I_3N_2	705.7d
I_3N_3	718.3d

*According to Duncan's test, the means with similar letters in each column are not significantly different at 5% probability level. I_1, I_2 and I_3: Irrigation after depletion of 30%, 40% and 50% field capacity of soil water, respectively.

N_1, N_2 and N_3: Consumption of 140, 180 and 220 $kg.N.ha^{-1}$, respectively.

Prasertask and Fukai (1997) stated that in drought stress conditions, with the increase of soil nitrogen, the absorption of this element from the soil increases, although the effect of nitrogen consumption is less than when sufficient water is consumed. Mahlooji *et al.* (2023) reported that when the plant is under drought stress, the use of nitrogen aggravates the lack of water in the plant and reduces seed yield. The results of the study by Pandey *et al*. (2000) regarding corn showed that the simultaneous increase in soil moisture and nitrogen leads to an increase in corn yield, on the other hand, at a constant level of soil moisture (low or high), an increase in nitrogen will lead to increased yield. The slope of yield increase per unit of nitrogen consumption is higher than the increase of each unit of irrigation.

Nitrogen absorption is more dependent on nitrogen consumption than reacting to water consumption, although water stress leads to a decrease in consumption nitrogen absorption, these researchers reported that in drought stress conditions, the amount of nitrogen needed to achieve maximum economic yield, 8-15% was less compared to optimal irrigation conditions. On the other hand, Russele *et al*. (1981) stated that the optimal amount of nitrogen to achieve the maximum yield under different irrigation treatments is the same and this situation is caused by the decrease in the efficiency of nitrogen use in the conditions of water shortage in the soil. According to these researchers, nitrogen absorption is limited in drought stress conditions, but this does not mean that nitrogen consumption should be reduced in such conditions, because nitrogen absorption from the soil is necessary for the survival of the aerial part even in the absence of rainfall or lack of moisture in the soil. Importantly, nitrogen consumption in soils with low nitrogen but sufficient water increases the efficiency of water consumption. Water often controls plant growth and absorption of nutrients is related to water availability. In addition, lack of water during the establishment stage of the corn plant can cause the death of young plants and reduce the density of the plants. The main effect of lack of water in the vegetative stage is to reduce the growth of leaves, as a result, the plant receives less light. Around the flowering stage (from about 2 weeks before to 2 weeks after the emergence of silks), corn is very sensitive to drought stress. If drought occurs during this stage, the grain yield will be seriously affected. During the grain filling period, the main effect of drought is the reduction of grain size. Basically, in the condition of water shortage, the corn plant makes major changes in its metabolic processes to deal with the negative effects of drought stress. These changes mainly include changes in the intensity of absorption, metabolism, the nitrogen transport, as well as the redistribution of this element and carbohydrates from storage organs. Knowing the set of these processes for use in agricultural programs is of special importance. In general, in a situation where there is not enough water, the management of favorable conditions is not effective and usually leads to the wastage of production resources, especially water and nitrogen. In such conditions, the efficiency of water and nitrogen consumption decreases. Therefore, under the conditions of lack of water in the soil, which affects the absorption of nutrients, especially nitrogen, it is necessary to establish a balance between the nitrogen consumption and the provision of moisture in the soil in order to increase the productivity of water and nitrogen.

Estimation of production in conditions of limited nutrients

Quantifying the effect of nutrient deficiency on growth rate reduction relative to potential is much more complicated than water limitation. Most of the research done on this topic focuses on nitrogen limitation. The speed of nitrogen absorption in potential conditions (DN kg N per hectare per day), which is called nitrogen demand, is equal to the difference between the maximum amount of nitrogen in the plant (kg N per hectare) and the actual amount of nitrogen in the plant.

Equ.1. $DN=(N_{C,m}-N_{C,a})/T_C=(W*NC_m-N_{C,a})/TC$

In this equation, $N_{C,m}$ is the maximum amount of nitrogen in the plant (kg N per hectare), $N_{C,a}$ is the actual amount of nitrogen in the plant (kg N per hectare), and TC is the delay in nitrogen absorption, which is about 2 days. W is the dry weight (kg per hectare) and NC_m is the concentration of nitrogen in the plant (kg of nitrogen per kg of dry matter). The actual absorption of nitrogen by the plant (dNc) is equal to the minimum amount of demand (DN) or the maximum supply of nitrogen by the soil (Ns).

Equ.2. dNc = Min(DN, Ns)

Therefore, under these conditions, the growth rate is a function of the nitrogen concentration in the plant.

Equ.3. $Ga/Gp= (NC_a-NC_{mn}) / (NC_{cr} - NC_{mn})$

In this equation, Ga and Gp are respectively the actual growth rate and potential (kilogram of dry matter per hectare per day) and NCa is the actual nitrogen concentration of the plant, NCcr and NCmn are respectively the critical concentration of nitrogen and the minimum concentration of nitrogen in the plant (kilogram of N per kilogram of matter dry plant).

Equ.4. NCa = Nc, a / Wt = actual amount of nitrogen in the plant / available biomass or current weight

The minimum and maximum amounts of nitrogen in the plant are different depending on the plant organ and among different crop species, and it decreases with the progress of the development stage. In the case of C_3 annual species, the maximum amount of nitrogen in the aerial parts of the plant decreases from 0.05 kg N per kg of dry matter during germination to 0.025 in the flowering stage and 0.018 in the ripening stage. In these plants, the critical amount of nitrogen is around 65% of its maximum amount and the minimum amount of nitrogen is around 0.008 kg of N per kg of dry matter. The maximum amount of nitrogen in C_4 annual species is similar to C_3 plants, but the critical and minimum nitrogen values in these species are almost half of the amount of C_3 plants. This ratio {(NCa-NCmn) / (NCcr-NCmn) } or Ga/Gp is actually a reduction factor that describes the severity of the decrease in the actual growth rate compared to the potential growth based on the amount of nitrogen limitation. The application of this relatively simple method in some crop plant growth models that simulate growth under nitrogen limitation has brought favorable results (Khajeh Hosseini and Koocheki, 2012; Connor *et al*., 2011).

5. CONCLUSION

In general, it can be concluded that in arid and semi-arid regions, where water and irrigation form the axis of agriculture, and the coordination of all agricultural operations is necessary for optimal use of water and maximizing yield per unit of water consumed (For this reason, words such as Water

Productivity and Crop Per Drop have become common), the existence of optimal moisture conditions is not always possible due to the constant fluctuations of climatic conditions and the degree of producer management. However, the study of crop management (such as use of different amounts of nitrogen density) has mostly been carried out under favorable moisture conditions, although it is necessary to change the management in unfavorable or less favorable conditions in order to achieve the appropriate amount of yield, It also kept the efficiency of resource consumption high. This will reduce the cost of corn production on the one hand and unnecessary consumption of resources such as nitrogen on the other hand. In case of not paying attention to agricultural management, in addition to increasing the cost and reducing the efficiency of using resources, the expected yield will not be achieved.

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FOOTNOTES

CONFLICT OF INTEREST: Author declared no conflict of interest.

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