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THE DETERMINATION OF ECONOMICALLY OPTIMUM NITROGEN DOSE IN SAFFLOWER PRODUCTION UNDER DRY CONDITIONS

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Abstract

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It is necessary to give a sufficient amount of nitrogen to a plant for optimum yield and high-quality production. It is economically and environmentally important to determine the right amount of nitrogen needed by plants. To determine optimum nitrogen dose in safflower production under dry conditions, data obtained from two separate field studies carried out in 2004 and 2005 have been used in this study. The relationship between the nitrogen amount applied and safflower yield was defined by using a quadratic function. Economically optimum N dose was calculated by marginal analysis. Accordingly, an economically optimum N level which is needed to be applied for a profitable production was calculated as 31.75 kg ha^{-1} for 2004 and 33.75 kg ha^{-1} for 2005. By using N at economically optimum level, it will prevent the environment from pollution of 48.50 kg ha^{-1} N and 48.92 kg ha^{-1} N according to the data for 2004 and 2005 years, respectively. In addition, it will decrease input cost by 64.51 NTL ha^{-1} and 65.06 NTL ha^{-1}.

Key words: Economically optimum, marginal analysis, quadratic function, safflower

Introduction

One of the most important methods for increasing agricultural production is to increase the efficiency of fertilizer dose. With this aim, optimum fertilizer application ratios; fertilizer content; nutritional requirements of the plant during the growth season; and the amounts of nutrition present in the soil should be ascertained (Dong et al., 2005; Alivelu et al., 2006).

In addition to factors such as the type and species of plant, soil structure, presence of organic materials and nitrogen, precipitation and soil moisture; the form, type and timing of nitrogen applications are also crucial to the benefit of culture crops with regard to nitrogen and in their nitrogen losses.

Fertilizing with nitrogen is one of the most important factors determining yield due to its multi-dimensional effects on the growth and development of safflower. Safflower has a higher need for Nitrogen than other nutritional elements for its optimum vegetative and generative development and this need is generally met by nitrogen applications.

Nitrogen need of safflowers change, depending on the adequate nitrogen in the soil, soil productivity and

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preceding crop (Armah-Agyeman et al., 2002; Siddiqui and Oad, 2006). Moreover, nitrogen need of the soil where safflowers will be cultivated can also change depending on the type of plant cultivated in the previous year. This situation affects the amount of adequate nitrogen in the soil, consequently, the need of safflowers for fertilizers with nitrogen (Berglund et al., 1998).

Soils in dry and semi-arid areas have a low organic material rate (El-Fouly et al., 2001). Therefore, fertilizers with nitrogen turn out to be one of the largest inputs of "dry agriculture" systems. It is necessary to apply sufficient amounts of nitrogen to achieve optimum yield and a high-quality product. However, over-fertilization and insufficient fertilization applications lead to economic losses and discharge of excessive amounts of nitrogen in the nitrate from through washing (Grant, 2006).

Optimum nitrate amounts applied in agriculture have gradually gained importance in recent years, particularly for the plants cultivated in the scope of intensive agriculture. In general, fertilizer suggestions are made on the basis of the reactions given by the plants to different fertilizer dosages applied in field studies. Suggestions for fertilizers with nitrogen should be made so as to ensure a high-quality product, optimum yield, high profit and less environmental pollution risks (Belanger et al., 2000; Antoniadou and Wallach, 2002; Henke et al., 2007).

Safflower (which is resistant to drought, is a high-quality cooking oil plant, and is one of the most important oil seed plants used in bio-diesel production) is accepted as a promising plant for dry agricultural fields. With the widespread cultivation of this plant, great contributions will be made to the national economy in terms of fulfilling the demand and need of vegetable oil and bio-diesel production.

Fertilizing with nitrogen increases safflower yield considerably under dry conditions as well as irrigated conditions (Chaudhry, 1981). Under dry conditions nitrogen, with amounts changing between 34 – 120 $kgha^{-1}$, is used in safflower cultivation (Patil and Sabale, 1997; Kaffka et al., 2000). When we consider fertilizer and product prices, increasing the amount of the nitrogen will result in loss rather than profit for the producer and fertilizing the plant with nitrogen which exceeds the optimum amount will lead to a considerable loss in terms of yield (Engel and Bergman, 1997) in cases when the income to be obtained at the end of additional nitrogen application can not cover the additional cost. Due to the above-listed reasons, it is of great importance to determine appropriate fertilizer doses to be applied in safflower cultivation under dry conditions. Optimum nitrogen dosages for crop plants are determined by applying different statistical models to the data obtained from the studies conducted with several fertilizer dosages. To this end, different models are used today.

The main purpose of the current study is to determine optimum nitrogen dosage for safflower cultivation under dry conditions.

Materials and Methods

Collection of production data

A field experiment was conducted under irrigated at the Agricultural Experiment and Research Centre, the Faculty of Agriculture, and Ataturk University in Erzurum (29^{o} 55'N, 41^{o} 16'E; 1850 m above sea level), Turkey, during the 2004-2005 cropping seasons. The experimental design was a randomized complete block design with the four replicates. The soil at the experimental site was a clayey-loamy; a bit alkaline; poor in lime, organic materials and phosphorus which are good for plants; and sufficient in terms of potassium in both years. Long-term average (71-year average) precipitation for the growing season was 187.3 mm. Precipitation was much lower in 2004 than in 2005; Precipitation levels for the May through September growing season were 172.1 and 222.1 mm for 2004 and 2005, respectively. Mean temperatures were calculated for the growing season as 15.1^{0}C, 15.8^{0}C and 15.8^{0}C for 2004, 2005 and long-term mean, respectively. The relative humidity values were recorded to be 48.0% and 61.8% respectively: lower in 2004 and higher in 2005 than the average of the long years (52.6%).

In the scope of the study, ammonium sulphate was used as a fertilizer with nitrogen (21 N %) and triple super-phosphate as fertilizer with phosphor (46 P_2O_5%). Two cultivar (Dincer 5-18-1 and Yenice 5-38), 4 row spaces (15, 30, 45 and 60 cm) and 5 levels of fertilizer with nitrogen (0, 30, 60, 90 and 120 kg ha^{-1}) were used. During seedbed preparations, the fertilizer with phosphorus were mixed with the soil according to 40 kg ha^{-1} calculation (Kaffka and Kearney, 1998) and fertilizer with nitrogen according to 0, 30, 60, 90 and 120 kg ha^{-1} calculation to each plot before sowing. The plots were 0.6, 1.2, 1.8 and 2.4 m wide and 5 m long and consisted of four rows space 0.15, 0.3, 0.45 and 0.6 m apart. The distance between plots is 2 m. Sowings was performed on May 13, 2004 and May 15, 2005. Plot stands were over sown and hand-thinned at approximately the first four-true leaf stage to approximately 10 cm apart within a row. At maturity, one row from the edges of each plot and 0.5 m part of the beginning of each plot was considered as edge effect and two rows in the center were harvested.

Model selection and determination of economically optimum dosage

The averages of the types and cultivation dates in Polat's (2007) study were calculated to determine the economically optimum dosage and seed yield values pertaining to 2004 and 2005. In determining optimum nitrogen dosage, the model that defines the yield-fertilizer relation best is preferred. Linear, quadratic, square root and mitscherlich models were tried in this study and the relationship between yield and fertilizer dosage was found to be defined by the quadratic model in the best way.

Quadratic model:

Y is formulated as: $Y = a + bx + cx^2$

Y = seed yield (kg ha^{-1})

X = the dosage of the nitrogen applied (kg ha^{-1})

a, b and c are the parameters of the model.

The estimated maximum yield values are obtained in the model by finding "x" by equating the first derivatives of the reaction equations to zero and replacing "x's" in the formula with the figure obtained. Economically optimum fertilizer dosage is, on the other hand, determined via marginal analysis. In marginal analysis, the production function determining the fertilizer-yield relation is calculated as $Y=a+bx+cx$ (1) in quadratic function type. The nitrogen use dosage where the Marginal Revenue (MR) is equal to Marginal Cost (MC) is defined as economically optimum dosage. MR is calculated by differentiating the first derivative of the Total Revenue (TR) function. TR function is calculated by multiplying production function with product price (P_y). MC is, on the other hand, calculated by differentiating the first derivative of Total Cost (TC) function. Accordingly, TR function is calculated as $TR = P_y Y = P_y (a + bx + cx^2)$ (2) MR is calculated by differentiating the first x derivative of TR. In the light of this explanation, MR can be calculated as in the following equation: MR = dTR dx $= bP_y + 2 P_y cx$ (3)

Since the aim of the study is to determine optimum dose amounts of nitrogen dosages applied, only the amount of nitrogen is included in the TC function. Maximum yield is achieved when the marginal production (MP) is zero. MP is calculated by differentiating the first x derivative of Y. MP is calculated as follow $MP = dY/dx = b + 2cx$ (4)

The unit price of safflower is taken as 0.27 NTL (New Turkish Lira equals about 1.25 US Dollars as average of 2007 year) kg^{-1} and unit price of 1 kg of nitrogen in ammonium sulphate (N) as 1.33 NTL on the basis of the market prices of 2007.

Results and Discussion

Data used in this study was obtained by using the results of the studies conducted in 2004 and 2005 (Polat, 2007). According to this study, the relationship between these two variables was examined by analyzing the highest safflower yield. The model which defines this relation between using N and yield of safflower was obtained using the quadratic function (Table 1 and Table 2). According to the regression analyses results, nitrogen level used to obtain the highest total production is shown in Figure1 and Figure 2. However, it is aimed to determine a profitable production level rather than the nitrogen dosage used at the production level with the heights yield. Therefore, it is

Table 1
Estimation of the model determining the relationship between the nitrogen dosages applied and safflower yield obtained (2004)

$R^2 = 0.68$				
	Coefficients	Standard error	t	p-value
A	77.454.705	1.930.483	40.122	0
B	9.625.238	0.76227	12.627	0
C	-0.0606687	0.060913	-9.960	0

Table 2
Estimation of the model determining the relation between the nitrogen dosages applied and safflower yield obtained (2005)

$R^2 = 0.69$				
	Coefficients	Standard error	t	p-value
A	84.856.205	1.913.794	44.339	0
B	9.918.874	0.75568	13.126	0
C	-0.0627815	0.060387	-10.397	0

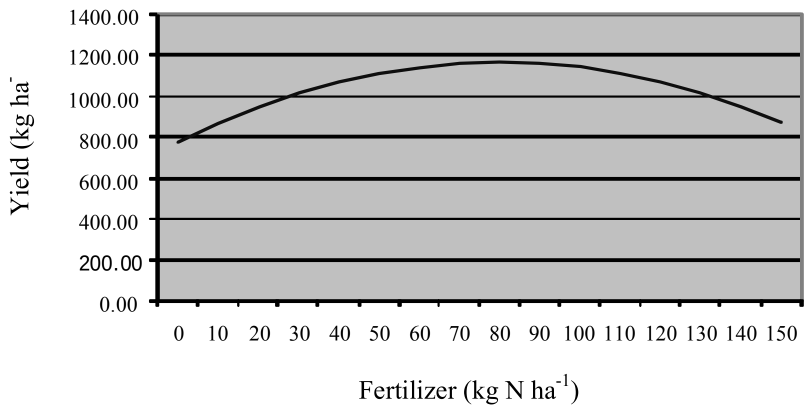

Fig. 1. According to the regression analyses results, relations between nitrogen level and safflower yield under dry conditions (2004)

considered whether the additional income (MR) brought by each nitrogen unit added covered additional fertilizer costs (MC) or not.

In the calculation of the use level of economically optimum input; additional income to be obtained from the production amount (Y) by adding one unit of the input used (X) is taken into consideration. The ratio of the additional change observed in Y product to additional change in X factor and the ratio of X factor price to Y product price should be equal. In the scope of these explanations, we can conclude that economically optimum nitrogen levels to be applied account for the point where MR is equal to MC for a profitable production. By multiplying the equation of

$Y = 774.55 + 9.63x – 0.06x^2$

which serves as the production function for 2004 with the product (safflower) price (0.27 NTL), we can obtain TR function (P_yY). Accordingly, TR function is;

$TR = 209.13 + 2.60x – 0.02x^2$

MR function, which is the first x derivative of TR function, is;

$MR = 2.60 – 0.04x$

TC function is, on the other hand, the function obtained by multiplying the price of the input used (1.33 NTL) with the input amount (P_xX). Accordingly, TC function is;

$TC = 1.33x$

The first x derivative of TC function is equal to MC. In this case,

MC = 1.33 NTL. To meet the requirement for the determination of optimum nitrogen use level, we equate MC to function (equation 3). In this case;

$1.33 = 2.60 – 0.04x$

and the value to be obtained shows that optimum nitrogen use dosage is 31.75 kg ha^{-1} for 2004. The

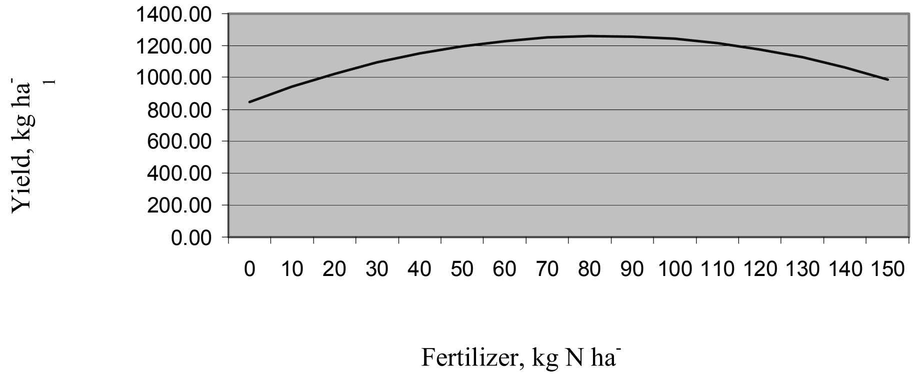

Fig. 2. According to the regression analyses results, relations between nitrogen level and safflower yield under dry conditions (2005)

Maximum yield for 2004 is the nitrogen dosage equating MP function to zero. In such case, the nitrogen dosage equating equation No. 3 to 0 is 80.25 kgha^{-1}.

When the same calculations are made for 2005; the production function is obtained by

$Y = 848.56 + 9.92x – 0.06x^2$

TR function and MR function (which is the derivate of TR function) are

$TR = 229.11 + 2.68x – 0.02x^2$

$MR = 2.68 – 0.04x$

TC function is equal to $P_x x$; however, its derivative MC is calculated as 1.33 NTL. Under these calculations and equations, the optimum nitrogen use dosage obtained in the study conducted in 2005 is calculated as (1.33 = 2.68 – 0.04x) 33.75 kg ha^{-1} nitrogen by equalizing MR function to 1.33 NTL which is MC value. Optimum nitrogen use dosage calculated for 2005 is found to be 33.75 kg ha^{-1}. Nitrogen dosage to be used in maximum yield for 2005 is the x value equating MP to zero. This value is 82.67 kg ha^{-1}.

It can be concluded at the end of the study that it is a rational application to decide the nitrogen amount to be applied to safflower under dry conditions between 31.75 kg ha^{-1} and 33.75 kg ha^{-1} in terms of economically optimum yield. In this way, the highest yield values decided as maximum yield can be achieved by using nitrogen amount between 80.25 kg ha^{-1} – 82.67 kg ha^{-1}(Figure 1 and Figure 2). In the similar studies made with the aim to determine nitrogen need in safflower production under dry conditions, it was reported that maximum yield of safflower was determined using 75 kg ha^{-1} N by Nasr et al. (1978), 60 kg ha^{-1} N by Katole and Meena (1988), 120 kg ha^{-1} N by Zaman and Das (1992), 50 kg ha^{-1} N by Patil and Sabele (1997).

On the other hand, economically optimum level can be realized by using nitrogen amount between 31.75 kg ha^{-1} and 33.75 kg ha^{-1}. In case nitrogen dose is based on economically optimum level, two important results come out. The first is that fertilizer cost can be reduced and profit can be increased by decreasing the fertilizer dose from maximum yield to economically optimum level. In this way, unnecessary excessive fertilizer dose can be prevented and contributions can be made to the national economy. The second important result is that dose of economically optimum fertilizer dosage can prevent discharge of excessive nitrogen in a nitrate form via washing and polluting the environment. As a result of this study, if the farmers use at the economically optimum level N dose, they can decrease input cost (N fertilizer) by 64.51 NTL ha^{-1}(48.50 kg ha^{-1} 1.33 NTL) and 65.06 NTL ha^{-1} according to the data for 2004 and 2005 years, respectively. In addition they can prevent the pollution of the environment by 48.50 kg ha^{-1} and 48.92 kg ha^{-1} N according to the data for 2004 and 2005 years, respectively.

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