Effect of Arsenic and Nitrogen Application on Grain Yield and Some Physiological Parameters of Safflower (Carthamus Tinctorius L.)

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***Abstract*—Arsenic causes physiological disorders in plants. In order to study effects of arsenic and nitrogen on safflower parameters, a plot experiment as completely randomized factorial design with three replicates was conducted in a greenhouse at university of Zabol, Iran. The nitrogen treatment was; N_1=75, N_2=150 and N_3=225 kg N ha^{-1}, and arsenic levels was A_1=0, A_2=30, A_3=60 and A_4=90 mg/kg.soil. Results showed grain yield was significantly affected by interaction nitrogen×arsenic and the highest grain yield was obtained at the N_2A_3 treatment. Data showed that application of nitrogen and arsenic had significantly effects on yield components (biological yield and number of seed per plant). By increasing arsenic concentration from A_1 to A_4, yield components decreased but by application of nitrogen, especial until N_2 level, these components increased. Arsenic and nitrogen application, significantly affected on carbohydrate and chlorophyll content in leaves. Under arsenic treatment, chlorophyll and carbohydrate content increased.**

***Index Terms*—arsenic, nitrogen, agronomy traits, safflower**

I. Introduction

Arsenic (As) is distributed widely in the environment, and results from weathering of soil parent material and human activities. In aerobic soils, arsenate (AsV) is the most stable and dominant species. The uptake of arsenate by plants has been studied extensively [1]. In an anaerobic environment under reducing conditions, arsenite (AsIII) is the dominant species. Both inorganic arsenic species are highly toxic to plants. Arsenate is a phosphate analog, and therefore it can compete with phosphate in the cytoplasm, replacing phosphate in ATP, leading to the disruption of energy flows in cells. On the other hand, AsIII is highly toxic to plants because it reacts with sulfhydryl groups (-SH) in enzymes, their cofactors and tissue proteins [2].

Arsenic is not a heavy metal, but it is related to them. In plants, arsenic is accumulated mainly in the root system, to a lesser degree in the aboveground organs, and causes physiological changes and damages [3], and reduction of the crop productivity. Arsenic inhibits the growth and fresh and dry biomass accumulation [4]. Apart from other factors, nutrients play vital role in the production of certain crops and its application is one of the quickest and easiest way in increasing yield per unit area. Among nutrients, nitrogen is one of major nutrients required by the plants for their growth, development and yield [5]. In addition to the amount supplied, the form of N available has significant effects on the growth and photosynthesis of plants and preference for the N sources nitrate (NO_3^-) and ammonium (NH_4^+) varies between plant species. Leaf N and chlorophyll (Chl) concentrations are important physiological parameters of detecting crop plant N status [6].

Since heavy metals may cause essential nutrient deficiency and even change the concentrations of basic nutrients such as N and P in plant tissues [7], better understanding of how heavy metal toxicity may be reversed by elevated macronutrient supply is needed. We hypothesize that abundant N supply will overcome the effects of arsenic concentrations. Therefore, the main aims of this work were to investigate the changes in the concentrations of nitrogen and arsenic in soil on grain yield, yield components and some physiological parameters of safflower (*Carthamus tinctorius* L.**).**

II. Materials and Methods

A plot experiment was conducted in a greenhouse at Agricultural university of Zabol, Iran during 2013. The experiment was laid out in a completely randomized 4×3 factorial design with three replicates. Each plot (55×35 cm) was filled with clay loam soil. Eight seeds of safflower (CV. Goldashd) were sown at uniform depth (1.5 cm) and after completion of emergence, thinning was done and four plants were maintained in each plot. Recommended dose of commercial fertilizer at the rate of 150 and 100 $kg.ha^{-1}$ P and K was supplied to each plot. Air temperature in greenhouse was controlled between the ranges of 25 and 33 ℃ during day and 18 and 23℃ during night. Relative humidity ranged from 40 to 80%. Light averaged 1074 μmol m^{-2} S^{-2}.

Manuscript received January 6, 2014; revised May 21, 2014.

doi: 10.12720/joaat.1.1.48-51

In this study, four arsenic levels A_1=0, A_2=30, A_3=60 and A_4=90 mg/kg soil was used as the sodium arsenate source and was applied in the plot before sowing of seeds. The rate of nitrogen treatment was N_1=75, N_2=150 and N_3= 225 kg N ha^{-1} was used as the Urea source (CH_4N_2O) and was applied in the plot before of sowing and after of thinning plants. At reproductive stage leaf chlorophyll content was measured using a hand-held chlorophyll content meter (CCM-200, Opti-Science, USA).The efficiency of chlorophyll fluorescence (Fv/Fm ratio) was measured on dark adapted leaf of plant with the help of Plant Efficiency Analyzer (Hansatech Instruments Ltd., Kings Lynn, UK). Soluble carbohydrates were determined according to the Horwitz [8], method. At the harvest time, data collected included yield of a plant (g/plant), biological yield or dry weight were measured after drying palnts at 70 °C for 48 h in an air oven (Schuurman and Goedewaagen) and plant height. The yield components included 1000-seed weight, number of seed per plant and number of capitula per plant in each experimental unit. At the end of experiment, all data were analyzed with SAS Institute Inc. 6.12 software. All data were first analyzed by ANOVA and significant differences between individual means were determined using Duncan multiple range test.

III. Results and Discussions

A. Grain Yield and Yield Components

Both arsenic treatment and nitrogen application had significantly effect on grain yield of safflower (Table I). The highest grain yield was recorded at the A_1 and the lowest at the A_4 treatment. In comparison with control, A_4 treatment caused 43.8% decrease of grain yield (Table I). Yield increases due to small additions of arsenic have been observed from corn, potatoes, rye, and wheat [9]. Similar increases in dry matter weight were also observed in tomato plants by Burló *et al.*, [10].

TABLE I GRAIN YIELD, YIELD COMPONENTS, CARBOHYDRATE, CHLOROPHYLL AND CHLOROPHYLL FLUORESCENCE IN SAFFLOWER AS AFFECTED BY ARSENIC AND NITROGEN RATE

Treatments	Grain yield	Biological yield	Number of seed per plant	Number of capitula per plant	Chlorophyll	Chlorophyll fluorescence	Soluble carbohydrate
		g/plant			SPAD value	Fv/Fm	(µg Glucose. g^{-1}.Fw)
							Arsenic (mg/kg soil)
A1=0	1.10a	7.42a	39.11a	5.33a	6.30ab	0.548a	9.83b
A2=30	0.77ab	6.42b	34.00a	5.00ab	5.94b	0.471a	13.58a
A3=60	0.91ab	6.40b	39.50a	4.22b	7.68a	0.508a	13.94a
A4=90	0.62b	5.36c	33.50a	4.22b	7.31ab	0.513a	14.23a
							Nitrogen (kg N ha^{-1})
N1=75	0.63b	5.61b	34.04b	4.25b	6.88a	0.46b	12.77ab
N2=150	1.15a	7.11a	48.75a	4.33b	6.93a	0.55a	12.43b
N3=225	0.75b	6.49a	26.79b	5.50a	7.36a	0.51ab	13.49a

Means followed by the same letter are not significantly different within rows and column according to Duncan's test ($P \leq 0.05$)

Grain yield in safflower increased significantly with the application of nitrogen fertilizer. The application of nitrogen at the rate of N_2=150 kg N. ha^{-1}, gave the highest (g/plant) and the N_1= 75 kg N. ha^{-1} produced the lowest of grain yield (Table I). The grain yield of safflower was significantly influenced by the interaction between nitrogen×arsenic (Table I). Grain yield until N_2 levels of nitrogen had positive response to arsenic concentration, and the highest grain yield was obtained at the N_2A_3 treatment (Fig. 1). Nitrogen influences all levels of plant function, from metabolism to resource allocation, growth, and development [11]. Arsenic is easily incorporated into plant cells through the high affinity Pi transport system. Naturally selected arsenic hypertolerance in plants, apart from as hyper accumulators, generally relies on decreased arsenic uptake, because of suppression of the high-affinity Pi uptake system [12]. Nitrogen causes increasing Pi and others nutrient elements uptake in plants [11], The primary yield components of safflower are biological yield, 1000-seed weight, number of seed per plant and number of capitula per plant. The analysis variance of data indicated that application of nitrogen and arsenic concentration (except number of seed per plant) had significantly effects on these yield components (Table I). However by increasing arsenic concentration from A_1 to A_4, yield components decreased but application of nitrogen especial until N_2 level, caused increased yield components (Table I).

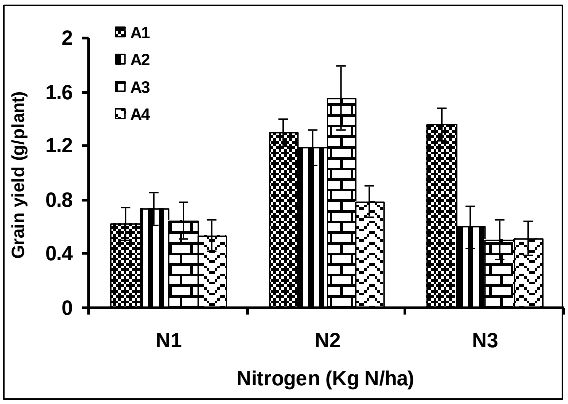

Figure 1. Effect of the arsenic and nitrogen on grain yield.

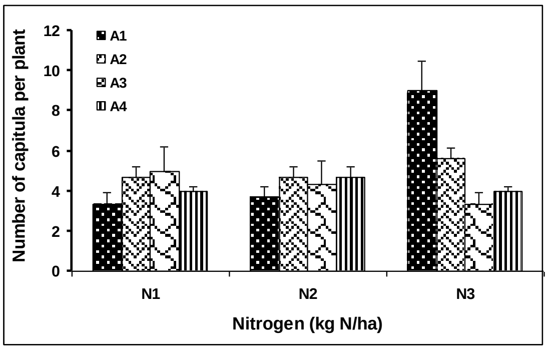

Figure 2. Effect of the arsenic and nitrogen on number of capitula per plant

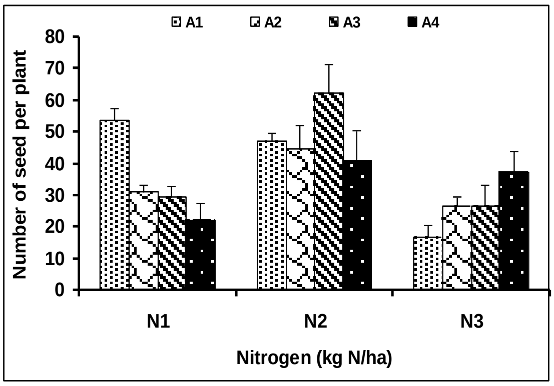

Figure 3. Effect of the arsenic and nitrogen on number of seed per plant

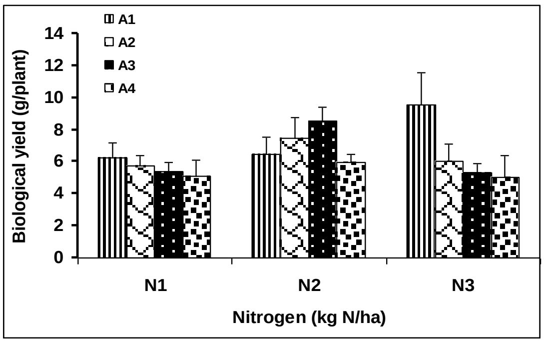

Figure 4. Effect of the arsenic and nitrogen on biological yield

Interaction between nitrogen×arsenic showed significant differences for all yield component traits investigated in this experiment (Table I). The obtained results reveals, the highest biological yield and number of capitula per plant were obtained from the N_3A_1 and the number of seed per plant at N_2A_3 treatments (Fig. 2-Fig. 4). Arsenic inhibits the growth and fresh and dry biomass accumulation [13]. Nitrogen one of the most important elements which application of it can promote tillering and leaf growth and leaf area duration in wheat [14]. The amount of nitrogen applied also affects the pattern of N uptake by the crop [15].

B. Chlorophyll, Chlorophyll Fluorescence and Soluble Carbohydrate Content

The results of this study indicate that application of arsenic and nitrogen in the growing medium significantly affected on carbohydrate content and the content of carbohydrate in leaves increased. Interaction between arsenic × nitrogen showed significant differences on soluble carbohydrate content in leaves of plants (Table I).

Table I reveals that soluble carbohydrate accumulation in leaf at the N_1 treatment, by increasing arsenic concentration from A_1 to A_4 increased. The highest soluble carbohydrate was obtained at N_1A_4 treatment. Addition of nitrogen to the growth medium, however caused increasing in the carbohydrate content, but this increase was only N_2 treatment.

Chlorophyll content in leaves was affected by arsenic treatment (Table I). A decrease in starch content and an increase in both reducing and no reducing sugars and polyphenol levels have been reported in leaves of maize [16].

Under arsenic treatment, chlorophyll content in leaf was increased. As arsenic was increased from control until to A_3, the chlorophyll content was increased (Table I). In comparison of chlorophyll, the Fv/Fm ratio, which characterizes the maximal quantum yield of the primary photochemical reactions in dark adapted leaves. The Fv/Fm was affected only by nitrogen treatment. The Fv/Fm values increased from the N_1 to N_2 treatment (Table I).

REFERENCES

[1] N. Singh, L. Q. Ma, M. Srivastava, and B. Rathinasabapathi, "Metabolic adaptations to arsenic-induced oxidative stress in Pteris vittata L. and Pteris ensiformis L," *Plant Sci*., vol. 170, pp. 274-282, 2006.

[2] R. D. Tripathi, S. Srivastava, S. Mishra, N. Singh, *et al*., "Arsenic Hazards: Strategies for tolerance and remediation by plants," *Trends in Biotechnology*, vol. 25, pp. 158-165, 2007.

[3] B. R. Wells and J. Gilmor, "Sterility in rice cultivars as influenced by MSMA rate and water management," *Agron J*., vol. 69, pp. 451-454, 1997.

[4] V. V. Stepanok, "The effect of arsenic on the yield and elemental composition of agricultural crops," *Agrokhimiya*., vol. 12, pp. 57-63, 1998.

[5] S. S. Singh, P. Gupta, and A. K. Gupta, *Handbook of Agricultural Sciences*. Kalyani Publishers, New Delhi, India, 2003, pp. 184-185.

[6] A. V. Baker and H. A. Mills, "Ammonium and nitrate nutrition of horticultural crops," *Hort Reviews*., vol. 2, pp. 395-423, 1980.

[7] A. Siedlecka, "Some aspects of interactions between heavy metals and plant mineral nutrients," *Acta Societatis Botanic Pol*., vol. 64, pp. 265-272, 1995.

[8] W. Horwiz, *Official Methods of Analysis of the Association of Official 245*, Analytical Chemist. 12th Edn. Association of official Analytical Chemists, Washington, DC, 1975.

[9] P. A. Gulz, S. K. Gupta, and R. Schulin, "Arsenic accumulation of common plants from contaminated soils," *Plant and Soil*., vol. 272, pp. 337-347, 2005.

[10] F. Burló, I. Guijarro, A. A. Carbonell-Barrachina, D. Valero, and F. Martínez-Sánchez, "Arsenic species: Effects on and accumulation by tomato plants," *J Agric Food Chem*., vol. 47, pp. 1247-1253, 1999.

[11] H. Marschner, *Mineral Nutrition of Higher Plants*., 2nd Academic Press. Ltd. London, 1995.

[12] A. A. Meharg and J. Hartley-Whitaker, "Arsenic uptake and metabolism in arsenic resistant and nonresistant plant species," *New Phytol*., vol. 154, pp. 29-43, 2002.

[13] N. Stoeva, M. Berova, and Z. Zlatev, "Physiological response of maize to arsen contamination," *Biol Plan*., vol. 47, pp. 449-452, 2003.

[14] J. Spiertz, V. O. S. De, and L. Hole, "The role of nitrogen in the yield formation of cereals, especially of winter wheat," in *Proc. Cereal Production, Royal Dublin Society*, Bultworths, 1984.
[15] R. Sylvester-Bradley, D. T. Stokes, R. K. Scott, and V. B. A. Willington, "A physiological analysis of the diminishing response of winter wheat to applied nitrogen," *Theory. Aspects of Applied Biology*., vol. 25, pp. 227-287, 1990b.
[16] E. Lozano-Rodriguez, L. E. Hernandez, P. Bonay, and R. Q. Carpena-Ruiz, "Distribution of cadmium in shoot and root tissues of maize and pea plants: physiological disturbances," *J Exper Bot*. vol. 48, pp. 123-128, 1997.

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