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Effect of Zinc and Nitrogen Fertilizer Rates on Yield and Yield Components of Oilseed Rape (*Brassica napus* L.)

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Abstract: In order to evaluate the effects of different levels of zinc sulphate (0, 30, 60 kg ha^{-1}) and of nitrogen (N) fertilizer rates (0, 50, 100, 150 kg ha^{-1}) on yield and yield components of oilseed rape (Hyola 308 cultivar), A field experiments were conducted at the Research Station of Agricultural and Natural Resources in Kaki region, (Bushehr Province) during two growing seasons of 2007/08 and 2008/09. Zinc sulphate application had no significant effect on plant height and 1000- grain weight but significantly increased number of branches, pods per plant and seed yield. Increase N fertilizer application significantly increased plant height, number of branches, pods per plant and seed yield. Results showed 60 kg ha^{-1} of zinc sulphate and 150 kg ha^{-1} of nitrogen fertilization had the highest grain yield, number of pods per plant and 1000- grain weight.

Key words: Nitrogen · Zinc · Grain yield · Oil percentage

INTRODUCTION

Rapeseed (*Brassica napus* L.) is one of the oil seed crops that is becoming an attractive source of vegetable oil in Iran. It is a new oilseed crop in Iran and its cultivated area has been currently expanding. Rapeseed has some appropriate agricultural characteristics such as cultivation under different seasons, rotation with cereals and high quality oil [1]. In highly calcareous soils in southern Iran, low level of available Zn may lead to a nutritional disorder. Zinc was one of the first minerals known to be essential for plants, animals and man. Among the micronutrients, Zn deficiency is most widespread on a wide range of soils in cold and warm climates [2]. The degree of deficiency is influenced by the soil pH, reserves of organic matter, other nutrients essential for plant growth and even herbicide applications. Other studies indicated that zinc deficiency in plants can be corrected fairly readily by application of inorganic zinc salts such as $ZnSo_4$ to the soil [2]. Application of P fertilizer may increase Zn deficiency in plants [3]. Zn-P interaction is well documented in a number of plant species [3, 4]. Zinc is a metal component or a functional, structural, or regulatory co-factor of a large number of enzymes [4]. Zinc is also involved in the synthesis of Indole Acetic Acid (IAA), so deficiency leads to changes the growth habit of plants, including rosetting and reduction in leaf size. The role of Zn in subsoil nutrition is particular interesting because of its importance in maintaining membrane integrity of root cells [5]. In rapeseed, root growth was impaired and seed yield was severely depressed when Zn was omitted from the subsoil [6]. Nuttal *et al.* [7] found accessible of the rapeseed to the Zinc would be important although the absorption and the rapeseed in comparison with the wheat (*Triticum aestivum* L.) would need two times Zinc. As a result of drought stress in the rapeseed, for the stress inside the levels of the soil the Zn would be out of the plant reaches and would reduce harshly [8]. The reduction of the zinc elements as a result of dryness would cause the amount of Oxides and it would preventing from the transferring the Indole Acetic Acid (IAA). The reduction of the amount of Oxides would be as a result of increasing activity of the IAA Oxides [9]. In a research perform on the 5 variety of rapeseed in the humid condition and in the 30% capacity of the field and 70%. Vays *et al.* [10] observed that the amount of zinc has been reached to its minimum amount, means 18 mg kg^{-1} in the stress condition and this effect had been limited in the aerial parts and the functioning had reduced harshly. Kimber and McGregor [11] reported that the Zn content of canola leaves were highest compared with other micronutrients. Zinc deficiency in soils can result in stunted growth with fewer branches and reduced canola seed yield by 20 to 30%. Zinc deficiency also decreased the oil contents Rapeseed has a high requirement for N [3]. Several studies have shown that N is a critical limiting

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nutrient in rapeseed production [3, 12, 13, 14]. Canola is extremely sensitive to N placed with the seed [3]. Nitrogen is a very important factor to achieve optimum yield in rapeseed and high rates of nitrogen doses regarded as a nitrogen demanding crops [11]. Nitrogen increased yield by influencing a variety of growth parameters such as branches, buds per plant and by producing more vigorous growth as reflected by increaseing stem length, number of flowering branches, total plant weight, seeds per pod [12], number and weight of pods and seeds per plant [3, 1). Jackson [13] found that the relationship between total plant yield and N reflects the tendency of canola to exhibit an indeterminate growth habit when nutrients and water were essentially unlimited. Who obtained optimal oil yield in the same range as seed yield, even though a negative relationship exists between oil content and increased N levels. Starner *et al*. [15] reported that application of N up to 100 kg/ha in canola plants increased significantly the seed yield ,while oil yield was not significantly affected. Nitrogen application usually decreased the oil and increased protein contents of rapeseed [16]. Application of nitrogen fertilizer at rates higher than the optimum requirement for crop production increased the nitrate accumulation below the root zone and pose a rise of nitrate leaching [17]. Ozer [18] reported that nitrogen application up to 100 kg ha^{-1} was sufficient for fertilizer requirement in rapeseed crop. Ahmadi and Bahrani [19] found that increase N application significantly increased seed yield, number of pods per plant and seeds per pod,while the highest seed yield was obtained with the rate of 225 kg N ha^{-1} under full irrigation conditions. Duration of growth, rate of production and harvest index are crucial for enhancing biomass and seed yield. During the growth cycle, establishment of the stand, flower initiation, use of radiation and availability of assimilates for pod set and seed filling are decisive factors influencing yield [6, 33]. The objective of this experiment was to determine the effects of different levels of zinc sulphate and nitrogen (N) fertilizer on yield and yield components of oilseed rape (Hyola 308 cultivar) in southern part of Iran.

MATERIALS AND METHODS

A field experiments were conducted at the Research Station of Agricultural and Natural Resources in Khaki region, Bushehr Province (51° 31′ E, 28° 20′ N and 60m) during two growing seasons of 2007/08 and 2008/09). Mean monthly temperatures and rainfall rate for two years of study and 30-years means of the region and some properties of soil are shown in Tables 1 and 2. The experiment was conducted as split plots arranged in randomized complete block design with four replications and comprised three Zinc sulphate levels (0, 30 and 60 kg ha^{-1}) as main plots and four N levels (0, 50, 100 and 150 kg ha^{-1}) as sub plots. Zinc sulphate fertilizer applied preplant and incorporated. Phosphorus fertilizer at a rate of 150 kg ha^{-1} in form of superphosphate was added before planting and nitrogen fertilizer in form of urea (46% N) which equally applied at both stem elongation and before flowering time.

Table1: Mean air temperature and rainfall values during the years of experiment and 30-year means at the Research Station of Agricultural and Natural Resources in Kaki region, Bushehr Province. Iran[a].

	Rainfall (mm)			Temperature (°C)		
	2007-2008	2008-2009	1988-2008	2007-2008	2008-2009	1988-2008
Sep-Oct	0.0	0.0	0.0	31.1	29.1	29.1
Oct-Nov	4.5	9.1	0.8	26.3	27.3	25.8
Nov-Dec	2.0	70.0	37.8	23.6	22.6	23.0
Dec-Jan	44.8	20.0	74.2	8.0	18.2	17.0
Jan-Feb	73.0	15.0	90.7	12.0	13.7	15.0
Feb- Mar	35.0	0.5	44.8	14.5	15.9	15.3
Mar-Apr	0.0	57.0	18.7	17.1	19.0	17.3
Apr-May	1.8	0.8	4.8	23.4	22.1	20.1
May-Jun	0.8	0.5	0.8	28.8	26.5	27.7
Jun- Jul	0.0	0.0	0.0	31.0	30.6	31.0
Jul-Aug	0.0	0.0	0.0	31.3	29.8	32.0
Aug-Sep	0.0	0.0	0.0	31.2	33.0	31.8
Total	161.9	172.9	272.6	-	-	-

[a]Unpublished report, Irrigation Department, College of Agriculture, Shiraz University, Shiraz, Iran.

Table 2: Some chemical and physical properties of soil of the experimental location

Organic matter (%)	0.30
Nitrogen (%)	0.08
Phosphorus (mg kg^{-1})	21.01
Potassium (mg kg^{-1})	118.00
Zinc (mg kg^{-1})	0.23
Copper (mg kg^{-1})	0.20
Iron (mg kg^{-1})	3.92
EC (dS m^{-1})	1.43
pH	8.50
Soil texture	Loamy sand

The seeds were manually planted on October 21 and October 24 in the 1st and 2nd seasons, respectively in 2 × 5 m plots. The plots irrigated seven times during the growing period in both years. The preceding crop was tomato (*Lycopersicon esculentum* L.) in both growing seasons. Weeds were controlled both mechanically and by application Trifluralin (2.5 l ha^{-1}) as pre emergence herbicide.

All plots were harvested during the 2nd week of April in each season and number of branches and pods per plant, seeds per pod, 1000-seed weight, seed and oil yields were determined. Seed oil content was determined by Nuclear Magnetic Resonance (NMR) method. The data were statistically analyzed for each season and then combined for both years by SAS [21] and M STAT C systems and the means were compared by Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Zinc application had no significant effect on plant height,while zinc application significantly increased number of branches per plant and the highest number was obtained with 60 kg Zn ha^{-1} (Table 3). Single plants may have at 20-25 primary branches, many of which do not set pods due to intra-plant competition [20]. Kimber and McGregor [11] suggested that producing fewer basal branches and more pods on main stem and upper branches is considered to be one of the rapeseed ideotype characteristics.

Zinc application showed a significant increase in number of pods per plant and number of seeds per pod. It is evident that zinc element plays an important role in plants [4]. Reliy *et al.* [9] found similar increases in wheat and oilseed yield. Number of seeds per pod may be determined primarily by the ability of the individual pod to supply assimilates at the time when final seed number is being determined. Diepenbrock [20] reported that the ultimate number of pods per plant and number of seeds per pod are determined during a four week period and is very dependent on a continuous supply of assimilates. The relation between source and sink during this phase governs the availability of assimilates. Brar and Thies [22] found that pods were a source of photosynthates for seed growth. Zinc application had no significant effect on 1000 seeds weight. Diepenbrock [20] suggested that seed weight depends to a lesser extent on environmental conditions than other components of yield. Depending on patterns of flowering, the onset of seed growth of pods on different branches varies considerably. Seeds at lower positions on the plant tended to be smaller than those at other positions. McGregor [23] and Olsson [24] found that 1000-seed weight was not strongly or little influenced by environmental conditions, respectively. However, Krogman and Hobbs [25] concluded that 1000-seed weight was increased with irrigation and N levels.

The analysis of variance indicated that the application of Zn significantly increased seed yield as reported by Riley *et al.* [9]. The highest yield was obtained with the 60 kg Zn ha^{-1}. Increasing Zn levels provides better conditions for the pod formation and increases number of seeds per pod. Diepenbrock [20] suggested that the seed yield of individual plants is closely related to the number of pods per plant. Also, the seed yield reduction at pod formation was also associated with the reduction of the pods per plant [26]. Increasing average seed yield can best be achieved by simultaneously increasing the capacity of the sink and the source for seed filling. The most significant prerequisites for achieving this are an even distribution of plants, accelerated emergence and expansion of leaves form re-growth in spring until flowering, availability of assimilates during full flowering when most part of incoming radiation is reflected and synchronization of pod development, seed set and seed filling in relation to the hierarchy of branching [20]. The application of Zn had a significant effect on rapeseed oil. The oil content (%) of the seeds increased with Zn application. Taking the maximum yield and the most favorable oil content as primary objectives into consideration, the hihest oil content was obtained with an application of 60 kg Zn ha^{-1}. Oil is the most important parameter of rapeseed quality. Apart from the genetic factor, the content of oil in rape seeds is largely determined by mineral fertilization of the plants. Decrease in rapeseed oil content may be result from deficit of nutrients, among others of such micronutrients as zinc that control the metabolic transformations in the plants.

Table 3: Effect of Zn and N levels on yield and yield components of rapeseed (Average of two seasons

	Plant height	Branches per plant	Pods per plant	Seeds per Pods	1000-seed weight(g) (kg ha^{-1})	Seed yield (kg ha^{-1})	Oil yield(cm)
Zn (kg ha^{-1})							
0	119.4b	5.1c	68.3c	15.2c	3.4a	1560.4c	639.0c
30	129.4a	6.2b	89.4b	18.8b	3.5a	2397.4b	1030.5b
60	132.1a	7.5a	125.5a	22.3a	3.6a	3022.1a	1359.1a
N (kg ha^{-1})							
0	117.9d	5.0d	70.5d	15.8d	3.22b	1475.3d	619.2d
50	124.2c	5.9c	96.1c	19.4c	3.31b	2408.8c	1083.9c
100	131.5b	6.9b	131.6b	21.6b	3.35a	2798.8b	1203.2b
150	142.6a	7.8a	144.9a	24.1a	3.41a	3051.6a	1312.0a
Year							
2007-2008	128.1a	6.3a	103.3b	19.3a	3.4a	2167.2b	987.4b
2008-2009	125.3a	6.1a	105.7a	19.1a	3.2a	2387.5a	1025.4a

Mean of each group in each column and in each treatment with similar letters are not significantly different (Duncan 5%).

Increase N application levels significantly increased plant height as mentioned by Ahmadi and Bahrani [19] and Taylor *et al*. [27] and the highest plant height was obtained when applied 225 kg ha^{-1} N. Increase plant height resulted in an increase in pods per plant, seeds per pod and higher seed and oil yields.

Nitrogen application significantly increased number of branches per plant and the highest number was obtained with 150 kg N ha^{-1} (Table 3) which can be attributed to increase in absorption and translocation of assimilates and stimulating apical and lateral meristems to grow [28]. The application of nitrogen led to the development of more pods per plant and seeds per pod. The increase in number of pods per plant was partly due to the greatest number of flowering branches developed when nitrogen was applied. Mendham *et al.* [29] have argued that canola breeders should be aiming to produce plants with fewer pods but with a higher potential number of seeds per pod as this maximize seed survival and hence increases seed number per unit area. A similar ideotype has been suggested for both canola and mustard [8]. Increase N application significantly increased seed yield, mainly due increasing number of pods per plant and seeds per pod [30, 28] and the highest seed yield was obtained with 150 kg N ha^{-1} (Table 3). Krogman and Hobbs [25] indicated that both leaves and pods are important in photosynthesis and seed yield increases with adequate soil moisture. Allen and Morgan [31] reported that the highest seed yield which was obtained with higher N levels due to a greater production of seeds by a larger number of pods carrying seeds.

The interaction between N and Zn levels treatments showed that 60 kg Zn ha^{-1} and 150 kg N ha^{-1} application had the highest seed yield, number of branches per plant, pods per plant, oil yield and 1000-seed weight. Diepenbrock [20] found the number of pods per plant was the most responsive of all yield components in canola, whereas there was emphasis on number of flowers and pods [23] and pods per plant as important factors for yield compensation. The physiological restrictions to pod formation are related to poor crop growth and limited leaf expansion, both of which limit the most sensitive stage of initiation of inflorescences. N generally stimulates plant growth by means of an enlarged leaf canopy and a greater rate of leaf expansion, resulting in more pods [16]. Biological yield was increased with N and Zn application and the highest yield was obtained when 60 kg Zn ha^{-1} and 150 kg N ha^{-1} was applied. Diepenbrock [20] suggested that duration of growth is crucial for enhancing biomass and seed yield.

There was a significant difference between the number of pods per plants, oil and seed yields during the two growing seasons (Table 3). The seed (2387.5 kg ha^{-1}) and oil (1025.4 kg ha^{-1}) yields of 2st season were more than in the 1st season due to favorable weather conditions, higher and better rainfall distribution during crop growth seasons (Tables 1 and 3). Al-Kaisi *et al.* [32] reported that the interaction between irrigation and N on seed yield was significant and varied by year and also seed yield response to N levels was affected by irrigation and year. Nuttall *et al.* [7] found that the interaction effect of year and N was significant, indicating a wide range of response to applied N among years, because of

Table 4: Correlation coefficients between yield and yield components of rapeseed

Characteristics	Plant height	Branches per plant	Pods per plant	Seeds per pods	1000-seed weight	Seed yield
Plant height						
Branches per plant	0.219					
Pods per plant	0.682*	0.643**				
Seeds per pods	0.121	0.322	0.015			
1000-seed weight	0.861**	-0.421	-0.076	-0.976**		
Seed yield	0.865**	0.432	0.966**	0.643**	0.632**	
Oil yield	0.833**	0.221	0.045	0.603**	0.611**	0.964**
Biological yield	0.559**	0.623**	0.911**	-0.21	-0.12	0.677**

*,** significant at 0.05 and 0.01 level , respectively.

temperature, precipitation and soil nutrient effects. They mentioned that temperature and precipitation at the later stages of growth were most important factors affecting canola seed yield. Similar negative effects on seed yield have been observed with water stress during flowering and seed filling stages [33].

Correlation coefficients between yield and yield components in both growing seasons showed that the seed yield had significant correlation (r=0.966) with pods per plants as shown by Al-Kaisi and Yin [32] and Diepenbrock [20] (Table 4). Positive correlation of number of pods per plant with seed yield indicated that lesser number of pods per plant result in low seed yield. Therefore, seed yield per plant can be increased by increasing number of pods per plant [15, 33]. Seed yield had positive and negative correlations with plant height and 1000-seed weight, respectively as well. Diepenbrock[20] suggested that seed weight and pods per plant were negatively correlated and further a negative relationship had often been found between seed weight and seeds per pods. Sadaqat *et al.* [34] found that seed yield had significant positive correlations with plant height, pods per plant and branches per plant under drought conditions. There was a positive correlation between seed yield and branches per plant as mentioned by Tunturk and Ciftci [35].

In summary, it is concluded that Zn application can affect growth, yield and quality characteristics of rapeseed. The number of pods per plant and number of seeds per pod increased significantly with increasing zinc application. It can be concluded that supplemental Zn is of potential importance to control Zn deficiency in calcareous soils of arid regions. The crop had a high requirement for N fertilizer and 150 kg N ha^{-1} produced the highest seed and oil yields. Thus, providing sufficient Zn application and N fertilizer are important to produce higher rapeseed yield in this region. Further refinement of these findings will require additional work to address responses of different rapeseed cultivars to Zn and N application.

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