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Full Length Research Paper

Influence of plant growth regulators on growth performance and photosynthetic pigments status of *Eruca sativa* Mill.

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***Eruca sativa* Mill. (rocket) is an important plant that contains health promoting agents. The feasibility of applications of plant growth regulators (kinetin GA_3, spermidine and naphthalene acetic acid) was tested for improving performance of rocket plants. Application of plant growth regulators significantly enhanced the plant growth parameters (shoot fresh weight, root fresh weight, shoot dry weight, root dry weight and leaf area) and physiological parameters (chlorophyll *a* and *b*, proline and total soluble carbohydrates). It was, therefore, concluded that plant growth regulators enhanced the photosynthetic pigments, proline and total soluble carbohydrates that may be responsible for the dry matter production and better growth performance of rocket plants.**

Key words: Carbohydrates, chlorophyll, medicinal plant, plant growth regulators, proline, rocket.

INTRODUCTION

Eruca sativa Mill., Known as rocket, green rocket, true rocket, rocket salad, arugula, roquette, or white pepper in English, belongs to Brassicaceae family, is commonly distributed all over the world and is usually consumed fresh (leafs or sprouts) for its typical spicy taste. It has diversified medicinal and therapeutic properties including inhibition of tumorigenesis (Lynn et al., 2006), anti-ulcer (Alqasoumi et al., 2008, 2009), and hepatoprotective (Rafatullah et al., 2008) activities. It is rich source of health promoting agents such as iron, potassium, magnesium, calcium, beta-carotene, sodium, dietary fiber, vitamins A, B, C, E, flavonoids and glucosinolates (Steinmetz and Potter, 1991; Barillari et al., 2005; Lamy et al., 2008). Rocket, locally known as Jarjeer, is used as a diuretic, stimulant and in the treatment of stomach disorders and scurvy (Chopra et al., 1956). The seeds and tender leaves are considered as an aphrodisiac in Arabian countries. It is also used as a carminative and to alleviate abdominal discomfort and improve digestion. Seed of rocket plant possesses potent antioxidant and renal protective and diuretic activities and contains a large amount of thiofunctionalized glucosinolates along with erucic acid C22:1 (cis-13-docosenoic acid) (Mahran et al., 1991; Bennett et al., 2002; Falk et al., 2004; Lazzeri et al., 2004; Sarwar et al., 2007). It has a good industrial value because oil of this plant is used in as a lubricant, for soap making, as an illuminating agent, in massage, in medicines, as well as in cooking (Ahh et al., 2002; Miyazawa et al., 2002). Plant growth regulators (RGRs) are organic compounds that play an important role in several physiological and molecular processes of plants. It regulates the cell division, cell differentiation, root and shoots growth, and senescence of plants. PGRs are chemicals applied by a horticulturist to regulate plant growth and development. In addition, PGRs use as potential tools to increase defense mechanisms in medicinal plants (Nair et al., 2009). In view of the acclaimed medicinal properties of rocket in traditional medicine as well as in industrial uses as well as importance of plant growth regulators, we studied the effect of the plant growth regulators on the growth performance and content of photosynthetic pigments of *E. sativa* Mill plants.

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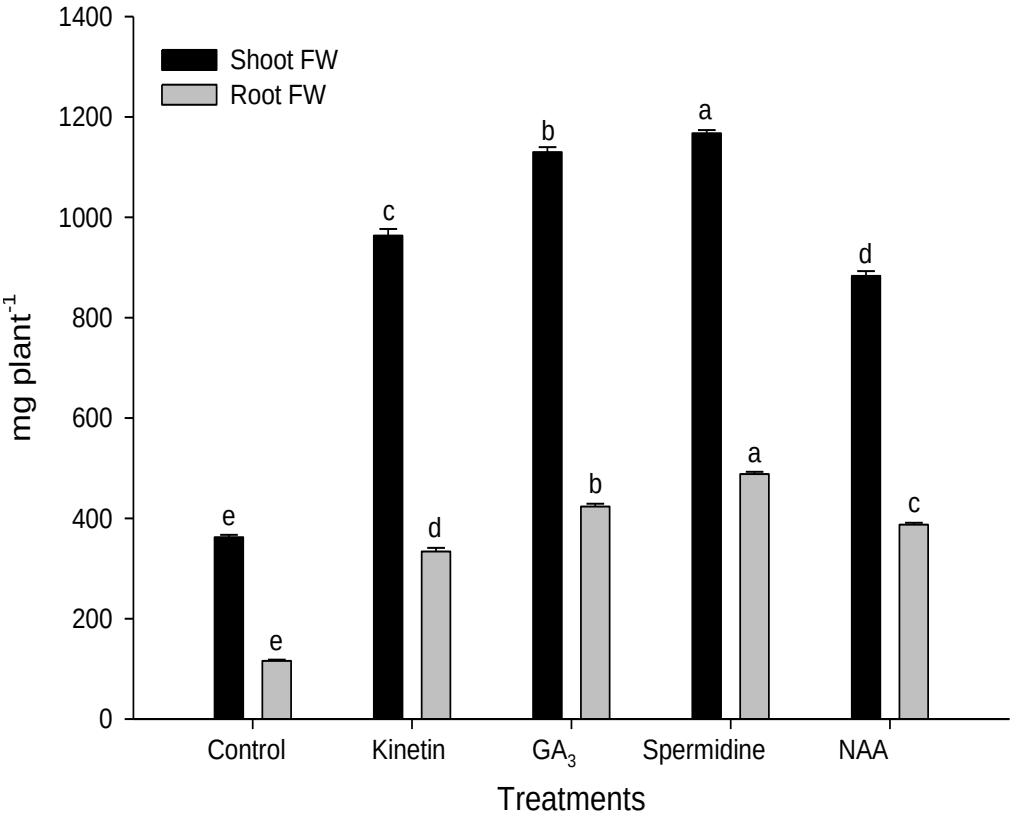

Figure 1. Effect of plant growth regulators on shoot and root fresh weight (FW) plant^{-1} of *E. sativa* Mill. Bars followed by the same letters show no statistical difference at *P<0.05* (Duncan Multiple Range Test). Average of four determinations are presented with bars indicating SE.

MATERIALS AND METHODS

The green house experiment was performed at Department of Botany and Microbiology, King Saud University, Riyadh, KSA. The seeds of rocket (*E. sativa* Mill.) were obtained from the local market of Riyadh, Saudi Arab. Before sowing, healthy seeds were surface sterilized with 1% sodium hypochlorite for 10 min, then vigorously rinsed with sterilized double distilled water (DDW). Ten seeds were sown 1.5 to 2 cm in deep in plastic pots (of 6 cm diameter), filled with perlite, supplied with Raukura's nutrient solution (Smith et al., 1983). The pots were arranged in a simple randomized design with a single factor and 4 replicates. The treatments also included (i) 0 (control), (ii) 10 µM Kinetin (KN), (ii) 1 µM GA_3, (iii) 0.5 µM spermidine (SD), and (iv) 100 µM α-naphthalene acetic acid (NAA). Nutrient solution was applied at 100 mL/pot every 2 days. When the plants were at the stage of 2 to 3 true leaves, the treatments were added to the pots with experimental rocket plants. The plants were sampled at 30 days after sowing to assess their growth characteristics [shoot fresh weight (FW), shoot dry weight (DW), root FW, root DW and leaf area(LA)], photosynthetic pigments [Chlorophyll (Chl *a*, and Chl *b*)], proline (Pro) and total soluble carbohydrates (total SC).

The plants were then placed in an oven run at 60°C for 48 h. These dried plants were weighed to record the plant DW. The leaf area was measured with the help of portable area meter, LI-COR, Model LI-3000, USA. The Chl was extracted from fresh leaves of experimental plants using the dimethyl sulfoxide (DMSO) method based on Barnes et al. (1992). Chl absorption in the extract was measured using ultraviolet/visible (UV-VIS) spectrophotometer.

Proline concentration was determined spectrophotometrically by adopting the ninhydrin method of Bates et al. (1973). We first homogenized 300 mg fresh leaf samples in sulphosalicylic acid. To the extract, 2 mL each of acid ninhydrin and glacial acetic acid were added. The samples were heated at 100°C. The mixture was extracted with toluene and the free toluene was quantified spectrophotometrically at 528 nm using L-proline as a standard.

Total soluble carbohydrates (total SC) concentration were estimated as described by Dubois et al. (1956), using glucose as a standard at 490 nm. Total water soluble carbohydrates were expressed as mg g^{-1} of dry weight (mg g^{-1} DW).

Statistical analysis

The data were analyzed statistically with SPSS-11 statistical software (SPSS Inc., Chicago, IL, USA). Mean was statistically compared by Duncan's multiple range test (DMRT) at P>0.05%.

RESULTS

The performance of the rocket plants was assessed in terms of shoot FW, root FW, shoot DW, root DW, LA, Chl *a*, *b*, content of proline and total SC. Application of all plant growth regulators significantly enhanced all traits of the plants (Figures 1 to 6). Application of KN, GA_3, SD and NAA increased all growth parameters. However,

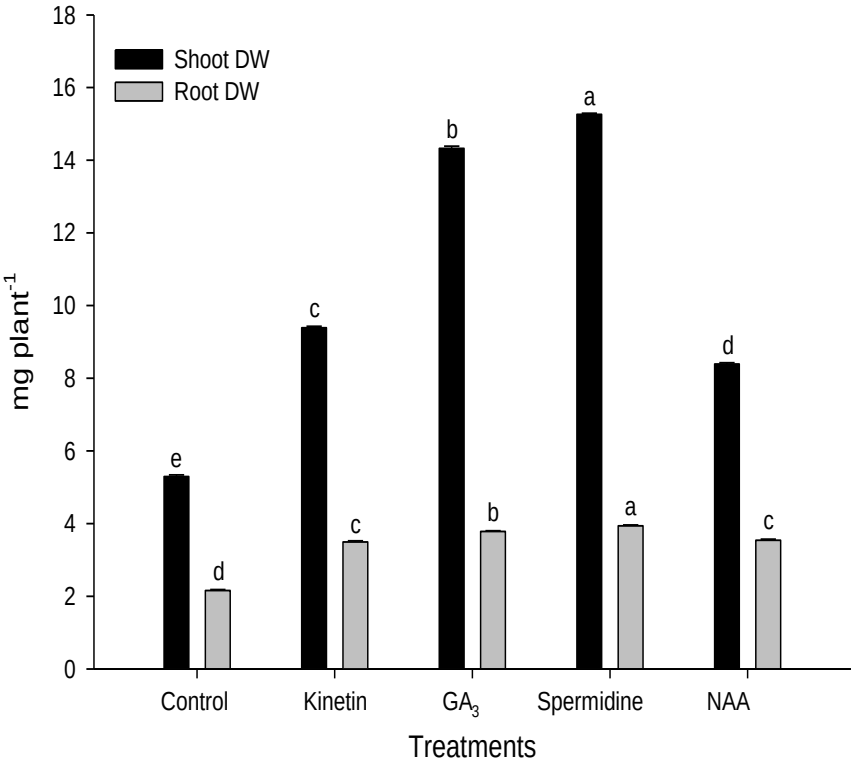

Figure 2. Effect of plant growth regulators on shoot and root dry weight (DW) plant^{-1} of *E. sativa* Mill. Bars followed by the same letters show no statistical difference at *P<0.05* (Duncan Multiple Range Test). Average of four determinations are presented with bars indicating SE.

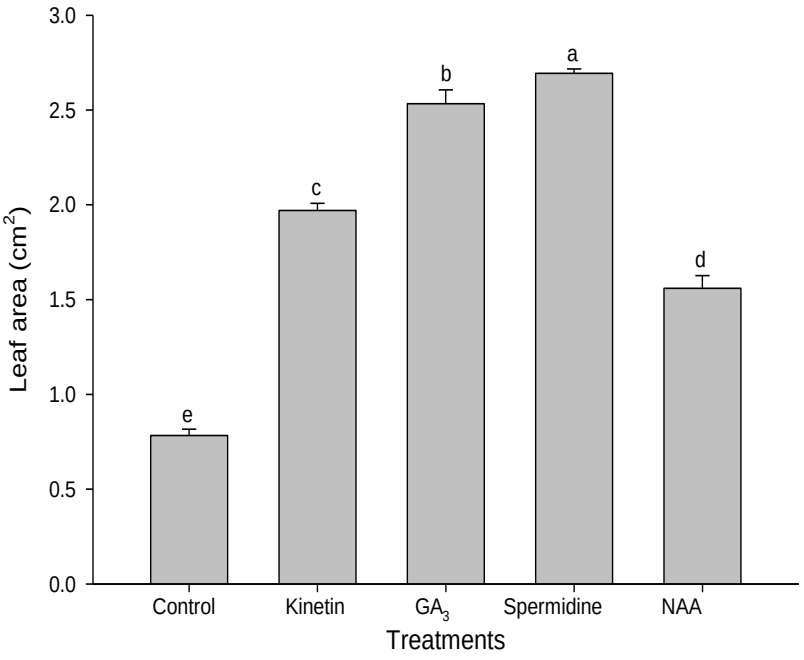

Figure 3. Effect of Plant growth regulators on leaf area plant^{-1} of *E. sativa* Mill. Bars followed by the same letters show no statistical difference at *P<0.05* (Duncan Multiple Range Test). Average of four determinations are presented with bars indicating SE.

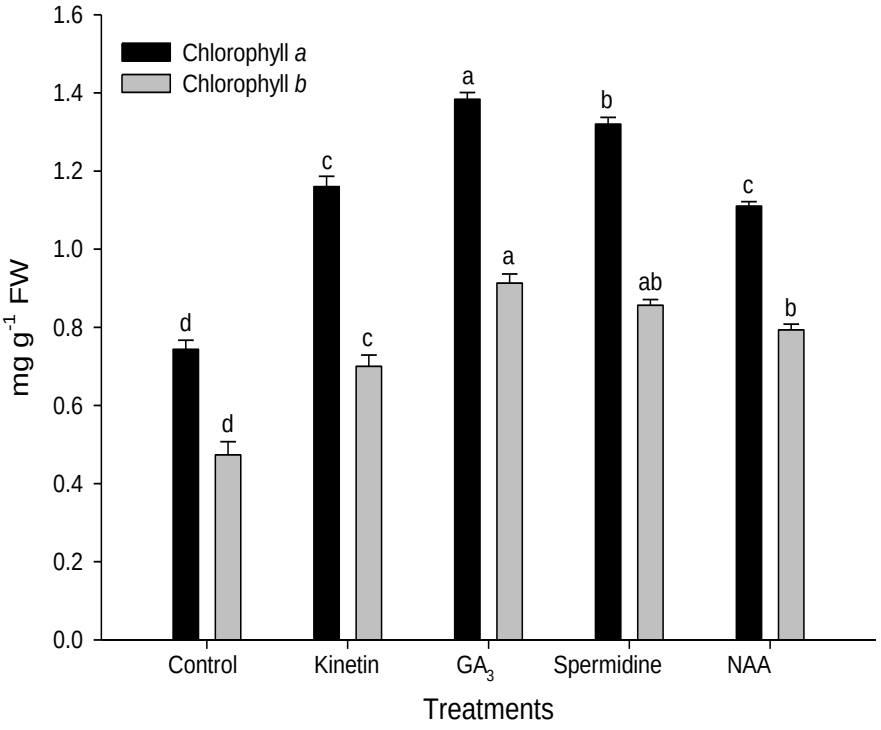

Figure 4. Effect of plant growth regulators on chlorophyll *a* and *b* content of *E.sativa* Mill. Bars followed by the same letters show no statistical difference at *P<0.05* (Duncan Multiple Range Test). Average of four determinations are presented with bars indicating SE.

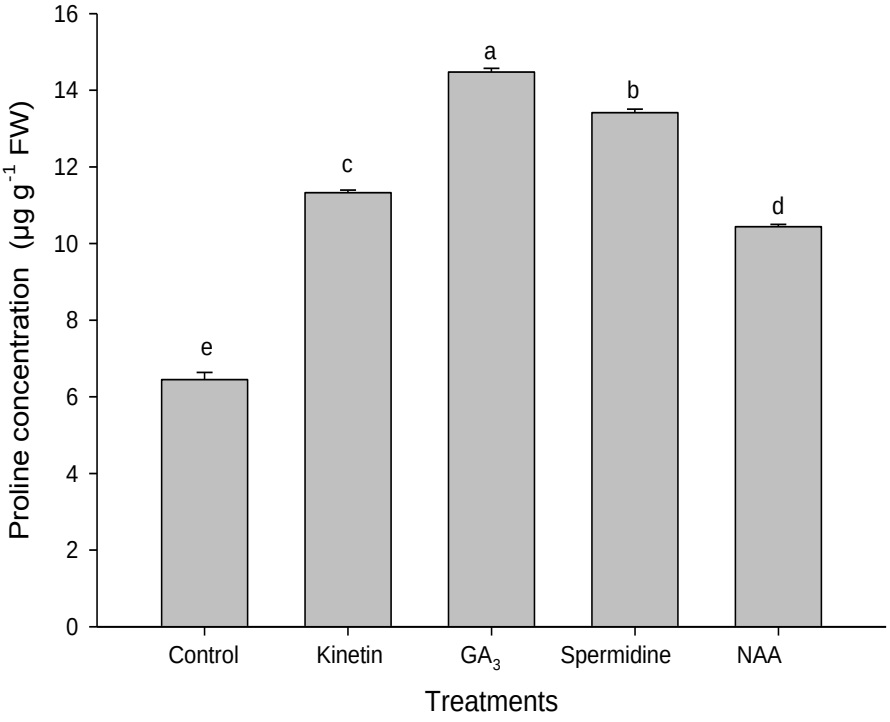

Figure 5. Effect of plant growth regulators on proline content of *E. sativa* Mill. Bars followed by the same letters show no statistical difference at *P<0.05* (Duncan Multiple Range Test). Average of four determinations are presented with bars indicating SE.

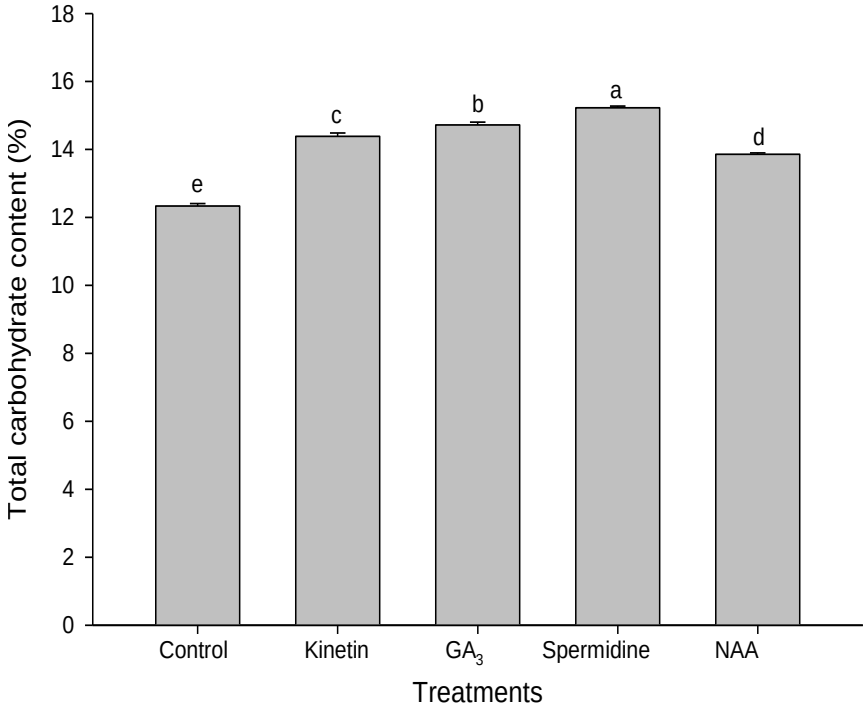

Figure 6. Effect of plant growth regulators on total carbohydrate content of *E. sativa* Mill. Bars followed by the same letters show no statistical difference at *P<0.05* (Duncan Multiple Range Test). Average of four determinations are presented with bars indicating SE.

treatment SD, followed by GA_3, produced more shoot FW, root FW, shoot DW, root DW, LA, than others. Treatment SD increased shoot FW by 222.25%, root FW by 335.94%, shoot DW by 188.47%, root DW by 82.41% and LA by 243.84% over the respective controls (Figures 1 to 3). However, application of KN, GA_3 and NAA increased shoot FW by 166.01, 211.86 and 43.76%, root FW by 198.26, 278.03 and 245.88%, shoot DW by 77.50, 170.89 and 58.60%, root DW by 62.04, 74.99 and 63.89% and LA by 151.5, 223.37 and 99.16%, respectively over the respective controls (Figures 1 to 3). The perusal of data (Figures 4 to 6) revealed that plant growth regulators significantly enhanced the photosynthetic pigments (Chl *a, b*), proline and total SC. Application of GA_3 gave maximum value for Chl*a*, *b* and Pro. However, application of GA_3 was at par with the application of SD for Chl *a*. Moreover, application of SD, followed by GA_3, gave the maximum value for total SC. Treatment of SD increased total SC by 23.42% over the control. Application of KN, GA_3, and SD increased Chl *a* by 56.06, 86.10, and 49.93%, Chl *b* by 47.90, 92.96, 67.61, respectively over the respective controls (Figures 4 to 6).

DISCUSSION

The most significant results obtained in the present experiment are that plant growth regulators significantly enhanced the plant growth and physiological characteristics of plant (Figures 1 to 6). It could be explained on the basis of their roles. KN, a kind of cytokinins, induces the cell division, synthesis of secondary metabolites, regulates the absorption of nutrients, and stimulates the synthesis of ribonucleic acid (RNA) (Seidlová and Krekula, 1977; Barciszewski et al., 1999; Mok and Mok, 2001). These findings are in accordance with the data on the effects of KN on plant growth (El-Quesni et al., 2007). The increase of plant growth as a response to GA_3 occurs as a consequence of cell division and cell elongation (Hirschi, 2004). GA_3 increases the plant growth, nitrogen use efficiency, nitrate reductase (precursor enzyme of nitrogen assimilation) and carbonic anhydrase (Afroz et al., 2005; Siddiqui et al., 2008; Khan et al., 2010; Siddiqui et al., 2011). In the present experiment, the better growth performance was recorded at NAA over the control (Figures 1 to 3). Similar results of increase in growth performance at NAA were found by Akter (2010) and Adam and Jahan (2011). The maximum growth promoting effect was found at SD because it may be due to an important polyamine form in plants, and binds with several negatively charged molecules, such as deoxyribonucleic acid (DNA), proteins, membrane phospholipids, pectic polysaccharides (D'Oraci and Bagni, 1987; Apelbaum et al., 1988; Basu et al., 1990; Pohjanpelto and Holtta,

1996; Tassoni et al., 1996; Messiaen et al., 1997; Barrachina et al., 2000). Polyamines play important role in protein phosphorylation and post transcriptional modification of DNA (Basu et al., 1990; Ye et al., 1994). It would be noted that the data on the enhancing effect of SD broadly confirmed the earlier findings of several workers, including Youssef et al. (2002); Abd El-Wahed and Krima (2004); Pandolfi et al. (2010). Pro is not only a universal osmoprotectant, it serves as an antioxidant and a source of energy, reducing equivalent nitrogen and carbon in plants (Kuznetsov and Shevyakova, 1999; Matysik et al., 2002). Pro also involves in flowering and developmental programs for rapid cell growth by providing energy (Mattioli et al., 2009).

In the present study, all plant growth regulators triggered synthesis of Pro in plants (Figure 5). This result agrees with the finding of Siddiqui et al. (2008) Khan et al. (2010), Siddiqui et al. (2011), who reported that production of Pro was higher in GA_3 treated plants. It is well established that carbohydrates provide rapidly growing cells with energy and with the carbon skeletons required to synthesize organic compounds (Taiz and Zeiger, 2010). In the present experiment, plant growth regulators induced the synthesis of Total SC (Figure 6) that lead to the better dry matter production (Figure 6). It is interesting that application of plant growth regulators enhanced the synthesis of TSC, it might be due to that higher content of photosynthetic pigments that is, Chl *a* and *b* (Figure 4).

Conclusion

The evaluation of the obtained results in the present study allows us to conclude that application of plant growth regulators enhanced the photosynthetic pigments, Pro and Total SC that may be responsible for the dry matter production and better growth performance of rocket plants.

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