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EFFECTS OF DIFFERENT PLANT GROWTH REGULATORS IN A VEGETATIVE CHAMBER ON SEEDLING MORPHOLOGY PARAMETERS OF YELLOW MUSTARD (*Brassica juncea* L.)

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Abstract

The aim of this study was to evaluate the sensitivity of yellow mustard (Brassica juncea L) to plant regulators compound growth by the root length, root surface area, root volume, stem length and surface area. The experiment consists of three varieties of yellow mustard (RETRO, FELICIA and PRIMA) and eight growth regulators (Albit, Vermistimd, Antistress, Agrios, Regoplan, Biofoge, Stimulate, Fast start). The results showed that the growth compound regulator was the main factor causing the difference in root length and had no correlation with the variety. Different types of plant growth compound regulators have significant differences in the growth and development of mustard. For RETRO, the growth compound regulator VERMISTIMD significantly increased root growth compared with the control. In FELICIA, the length of root has changed under the influence of seeds inoculation with growth compound regulator BIOFOGE. However, the treatment of ANTISTRESS significantly inhibited the root length of FELICIA and RETRO. In the study of the PRIMA, all the growth regulators had no significant or inhibitory effect on the growth of the roots. In addition, there were also differences in the sensitivity of compound growth regulators to root and stem, for stem growth of FELICIA, the growth compound regulator VERMISTIMD has the opposite effect on the stem surface area and BIOFOGE has a significant impact on stem surface area of PRIMA.

Key words*: mustard, plant growth regulator, culture room, morphology parameters.*

INTRODUCTION

Mustard is an important cash crop. It is one of the world's major sources of vegetable oil and vegetable protein. Mustard seed oil is famous for its rich content in isothiocyanates, which has been proved to have a key role in cancer prevention and bactericidal, and it has attracted more and more attention (Delaquis and Mazza, 1995; Trachootham et al., 2006; Melnik et al., 2015). Many studies have shown that mustard oil is considered one of the healthiest cooking oils, which is widely used for food, as well as in many industries - canning, bakery, confectionery, margarine, soap and pharmaceutical (Shekhawat et al., 2012; Zhuikov, 2014).

On the other hand, Mustard is favour by its appetizing flavor and preservative value (Bin Mustafa et al., 2018). The vigor of the plant at the beginning of germination has an important role for the whole growth period, especially root vitality. Previous studies have shown that increasing root length and increasing root volume are conducive to the accumulation of dry matter, and the surface area of roots is related to the rate of nutrient uptake (Ali et al., 2011). The plasticity of the root system is generally regulated by the availability of specific nutrients (López-Bucio, et al., 2003). In individual plants, the growth and development of roots is also affected by both the shoot and the above-ground environment.

As an exogenous stimulant, growth regulators have a prominent effect on promoting root growth, increasing crop yield components and quality formation (Wu et al., 2012; Setia et al. 1989). Furthermore, growth regulators play important roles in mitigating the effects of abiotic adversity on crops involved in the regulation the number and vitality of root systems (Ali et al., 2011; Yuan et al., 2014). Silva-Matos et al. demonstrated that foliar spray of humic substances enhances aerial part and root system of watermelon seedlings (Silva-Matos et al., 2019).

Maize treated with exogenous spermidine increased leaf area to enhance photosynthesis, promoted root growth to improve water

absorption, and finally increased maize yield (Li, 2019). Wang Tao reported that inoculating DJ515-2 fungal could improve the seed vitality of mustard and seed germination rate, root length, stem length and seed vitality index of the inoculated group increased by 20.0%, 52.4%, 56.3% and 83.7%, respectively compared with the control group (Wang et al., 2018). However, the use of single component regulators is generally targeted to conditions and crop varieties, not broad spectrum, limited yield increase, so the broad spectrum of compound regulators are strongly required in production. Liu Yali found that the mix of two or more plant growth regulators produces better results than a single application when applied to wheat leaf surfaces (Liu et al., 2005). Seed mixing with compound regulator can significantly increase the content of ZR and GA and the activity of catalase in leaves of progeria maize varieties, and reduce the content of ABA, H_2O_2 and MDA, thus delaying the progeria of leaves (Shao et al., 2014). Application of plant growth compound regulator can affect stress resistance and yield by adjusting plant height (Han et al., 2016).

Previous studies have reported the use of growth regulators to treat mustard seeds before germination can improve germination rate, uniform seedling emergence, strong stress resistance (Dalyan et al., 2018; Asgher et al., 2018; Sharma et al., 2016), but different genotypes of mustard have different responses to different plant growth compound regulators. Therefore, the objective of the study was to determine the sensitivity of mustard to different growth compound regulators in comparison with the growth and development of plants. Moreover, it is important guiding significance for the use of growth compound regulators in the field.

MATERIALS AND METHODS

Seeds of yellow mustard (*Brassica juncea* L.) cultivars RETRO, FELICIA and PRIMA. These cultivars were selected based on their yield potential, flowering/maturity groups, seed availability and popularity among Ukrainian growers during the period of these experiments. The seeds were procured from certified (commercial and/or Govt.) sources.

This experiment is the result of research cooperation between Henan Institute of Science and Technology (China) and Sumy National Agrarian University (Ukraine).

The experiment was carried out during the 2018 and 2019 years at the laboratories of Henan Institute of Science and Technology.

Eight compound regulators were used in the experiment, Albit, Vermistimd, Antistress, Agrinos, Regoplan, Biofoge, Stimulate, Fast Start, respectively. These seeds were soaked with either deionized water or different growth regulators. In all experiments seeds were germinated in plastic Petri dishes 90 mm square containing two germination papers saturated with Nutrient solution. All experiments were carried out in a culture room under a regime of 13 h light 11 h darkness, with temperatures of （30 ± 2）°C during the day and （25 ± 2）°C at night. There were 50 seeds per dish and the treatment had three repetitions. The composition of the nutrient solution is: 2.5 $mmol \cdot l^{-1}$ $Ca(NO3)_2$, 1 $mmol \cdot l^{-1}$ $MgSO_4$, 0.5 $mmol \cdot l^{-1}$ $(NH_4)H_2PO_4$, 2.5 $mmol \cdot l^{-1}$ KCl, 2 $mmol \cdot l^{-1}$NaCl, 2×10^{-4} $mmol \cdot l^{-1}$ $CuSO_4$, 1×10^{-3} $mmol \cdot l^{-1}$ $ZnSO_4$, 0.1 $mmol \cdot l^{-1}$ EDTA FeNa, 2×10^{-2} $mmol \cdot l^{-1}$ H_3BO_3, 5×10^{-6} $mmol \cdot l^{-1}$ $(NH4)_6Mo_7O_{24}$, and 1×10^{-3} $mmol \cdot l^{-1}$ $MnSO_4$. After 3 days of culture, plant samples were taken for measurement.

Measurement of morphological parameters

Mustard seedlings were separated into root and stem sections. Primary root length (PRL) was defined as the distance from the junction to the root apex and plant height defined as the distance from the junction to the shoot apex. The whole root was scanned using an Epson scanner (Seiko Epson Corp., Tokyo, Japan). The total root length (TRL) was calculated using WinRHIZO Version 4.0 b (Regent Instruments Inc., Quebec, Canada). Stems were scanned, then calculated using WinRHIZO.

Statistical analysis

Analysis of morphological parameters was based on five plants from three replicates of each treatment. All data were analyzed by ANOVA and Duncan's multiple range tests, and differences among compared means were deemed significant if $P < 0.05$. Data are expressed as mean ± standard error.

RESULTS AND DISCUSSIONS

Correlation analysis of variety and growth compound regulators on root length

There are many factors influencing root growth, and the correlation between varieties and growth regulators on root length was found the factors affecting root length are mainly derived from growth compound regulators, and the significance is 0 ($P < 0.01$), which has no relationship with the variety.

It is indicated that growth regulators are the main factors affecting root length (Table 1).

Table 1. Effect of growth compound regulators on root morphology of mustard seedlings in a vegetative chamber

Variety (Factor A)	Growth regulator (Factor B)	Root length cm	Root volume cm^3	Root surf area cm^2
RETRO	CK	3.94±0.61b	0.01±0.01abc	0.48±0.07bc
	ALBIT	3.89±0.6b	0±0c	0.44±0.05bc
	VERMISTIMD	4.76±0.7a	0.01±0a	0.58±0.06a
	ANTISTRESS	1.97±0.29d	0±0c	0.3±0.04d
	AGRINOS	3.96±0.36b	0.01±0.01abc	0.52±0.13ab
	REGOPLAN	3.22±0.3c	0.01±0.01ab	0.46±0.06bc
	BIOFOGE	3.58±0.48bc	0±0bc	0.41±0.05c
	STIMULATE	3.19±0.57c	0.01±0.01ab	0.47±0.09bc
	FAST START	3.34±0.31bc	0±0.01abc	0.41±0.1c
FELICIA	CK	3.81±0.55ab	0.01±0b	0.54±0.03ab
	ALBIT	3.58±0.51bc	0±0b	0.45±0.07b
	VERMISTIMD	4.31±0.62ab	0.01±0b	0.54±0.07ab
	ANTISTRESS	2.56±0.41d	0.01±0b	0.4±0.07b
	AGRINOS	3.82±0.58ab	0±0b	0.46±0.13b
	REGOPLAN	4.24±1.75ab	0.01±0.01a	0.73±0.47a
	BIOFOGE	4.65±1a	0.01±0b	0.58±0.08ab
	STIMULATE	2.72±0.27cd	0.01±0b	0.46±0.06b
	FAST START	3.87±0.43ab	0±0b	0.45±0.09b
PRIMA	CK	5.24±0.82a	0.01±0.01ab	0.56±0.09a
	ALBIT	3.88±1.04bc	0±0b	0.42±0.12bc
	VERMISTIMD	3.44±0.82c	0±0b	0.4±0.05c
	ANTISTRESS	3.58±0.91bc	0.01±0a	0.56±0.13a
	AGRINOS	4.57±0.81ab	0±0.01ab	0.53±0.1ab
	REGOPLAN	2.93±0.66c	0.01±0a	0.51±0.12abc
	BIOFOGE	3.37±0.5c	0±0b	0.4±0.06bc
	STIMULATE	3.13±0.74c	0.01±0a	0.48±0.08abc
	FAST START	3.5±1.17bc	0.01±0a	0.49±0.11abc

Note: Different letters in the same column indicate the significant level at 5%.

Effect of growth compound regulators on root morphology of mustard seedlings

Compared with the control, different types of plant growth compound regulators have significant differences in the growth and development of mustard roots (Table 1). For RETRO, the growth regulator VERMISTIMD significantly increased root length, root volume and root surface area according to observation, particularly in terms of the root elongation. The root length is 4.76 cm with treatment of VERMISTIMD, which is 0.82 longer than 3.94 cm in control. However, the root length combined treatment of ANTISTRESS was only 1.9 cm, which markedly inhibited the growth of the roots. In FELICIA, the length of root has changed under the influence of seeds inoculation with growth regulator BIOFOGE on 4.65 cm, while only 3.81 cm in control.

There was no significant change in root volume and root surface area with the inoculation of ANTISTRESS, but root length significantly ($p < 0.05$) reduced with the ANTISTRESS application by 2.56 cm. In the study of the PRIMA, all the growth regulators had no significant or inhibitory effect on the growth of the roots. The root length and root surface area were the largest without the growth regulator, which were 5.24 cm and 0.56 cm^2, respectively. Considering the root parameter, different varieties have different sensitivities to different growth regulators.

Effect of growth compound regulators on stem morphology of mustard seedlings

The results of the stem of the seedlings vary with growth compound regulators (Table 2).

Table 2. Effect of growth compound regulators on stem morphology of mustard seedlings in a vegetative chamber

Variety (Factor A)	Growth regulator (Factor B)	Stem length, cm	Stem surf area, cm^2
RETRO	CK	1.67±0.39a	0.45±0.09a
	ALBIT	1.42±0.26a	0.34±0.05ab
	VERMISTIMD	1.23±1.15a	0.35±0.22ab
	ANTISTRESS	1.19±0.21a	0.28±0.05b
	AGRINOS	1.57±0.42a	0.39±0.09ab
	REGOPLAN	1.66±0.21a	0.38±0.06ab
	BIOFOGE	1.73±0.26a	0.42±0.05a
	STIMULATE	1.54±0.24a	0.38±0.06ab
	FAST START	1.57±0.31a	0.37±0.08ab
FELICIA	CK	1.83±0.29ab	0.49±0.08a
	ALBIT	1.64±0.15b	0.38±0.05bc
	VERMISTIMD	1.4±0.43b	0.34±0.11c
	ANTISTRESS	1.52±0.21b	0.42±0.05abc
	AGRINOS	1.66±0.13b	0.42±0.04abc
	REGOPLAN	2.24±0.95a	0.42±0.09abc
	BIOFOGE	1.85±0.17ab	0.47±0.06ab
	STIMULATE	1.38±0.14b	0.33±0.01c
	FAST START	1.72±0.25b	0.4±0.07bc
PRIMA	CK	1.55±0.27ab	0.44±0.06a
	ALBIT	1.78±0.42a	0.43±0.09a
	VERMISTIMD	1.81±0.15a	0.43±0.06a
	ANTISTRESS	1.49±0.09ab	0.38±0.03ab
	AGRINOS	1.49±0.34ab	0.38±0.07ab
	REGOPLAN	1.48±0.57ab	0.31±0.08bc
	BIOFOGE	1.16±0.59b	0.27±0.1c
	STIMULATE	1.69±0.16a	0.4±0.03a
	FAST START	1.56±0.47ab	0.35±0.08abc

Note: Different letters in the same column indicate the significant level at 5%.

Stem length and surface area were no significant difference in the sensitivity of RETRO to different growth regulators compared to control. In FELICIA, the growth regulators of REGOPLAN and BIOFOGE slightly promoted the length of the stems, 2.24 cm and 1.85 cm, respectively, but the effect was not significant, while VERMISTIMD and STIMULATE have a significant inhibitory effect on the stem surface area. Seed pre-soaking with VERMISTIMD, ALBIT and STIMULATE increased the stem length and stem surface area for PRIMA, and BIOFOGE has a significant impact on stem surface area.

CONCLUSIONS

Plant growth compound regulators control most of the characteristics of growth system. Zhang Zigao reported that the morphology of wheat seedlings treated with complex excitin was improved (Zhang et al., 1993). HAN Yiqiang pointed out application of plant growth regulators B (main ingredients: ethephon 160 mg/l, 2-N.N-diethylaminocaproate 20 mg/l) obviously shortened the distance between the first node to forth node, then decreased the plant height, and shortened growth period duration, then insured the mature of 'Nongda 108'and increased maize yield (Han et al., 2016). The eight compound growth regulators used in this experiment can be divided into three categories: one is to promote seedling development, one is to inhibit effect, and the third is to have no effect. For example, the growth compound regulator VERMISTIMD significantly promoted root growth of RETRO according to data, particularly in terms of the root elongation, and growth compound regulator BIOFOGE significantly increased the root length of FELICIA, and the growth compound regulators of REGOPLAN and BIOFOGE slightly promoted the stem length. The pre-soaking with growth compound regulators VERMISTIMD, ALBIT and STIMULATE increased the stem length and stem surface area for PRIMA. On the other hand, root length significantly reduced with the ANTISTRESS application. The results also showed that there were differences in the sensitivity of root and stem to growth regulators, such as, the growth compound regulator VERMISTIMD has the opposite effect on the stem surface area of FELICIA The different compositions of the eight growth compound regulators used in this experiment may be the main reason for the different experimental results. Further studies will be conducted on the effects of the components of the compound growth regulator on plant development and the interactions between the components.

According to the results, the sensitivity of mustard to plant growth compound regulators varies widely. The growth compound regulator VERMISTIMD had a significant effect on root growth of RETRO and FELICIA, but had no significant or inhibitory effect on the roots growth of PRIMA variety. This may be due to differences in growth regulator composition and variety specificity.

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