

Effects of plant growth regulators on growth and yields characteristics in adzuki beans (*Phaseolus angularis*)

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Abstract Using the Jihong 8937 variety of adzuki bean (*Phaseolus angularis*) as material, two kinds of plant growth regulator (PGRs), PP333 and NAA, were sprayed on the leaves, in order to study their effects on the growing courses, dry matter accumulation and yields. Three concentrations for each of the PGRs were applied, with a naturally growing plant as the control (CK). Results showed that each concentration of PP333 could advance the developmental course but the NAA was reverse. There was no difference between the two kinds of PGRs in the whole growing course. The lower and medium concentrations of PP333 could increase the dry matter accumulation, but the others showed the contrary. The lower and the medium concentrations of these PGRs could increase the contents of dissolvable protein and chlorophyll, but their higher concentrations had inhabiting effects. Our research also found that their lower and medium concentrations could consistently increase this bean's yield, but the higher concentration reduced it. As a whole, the medium concentration of PP333 was found as the best combination to improve the growth and development of adzuki beans.

Keywords plant growth regulator, adzuki bean, growing characteristics, physiological index, yield

Introduction

The plant growth substances play important regulatory roles in plant growth by either exogenous application or endogenous production. It can not only regulate the process of endogenous metabolism, such as the synthesization of nucleic acids, proteins and enzymes, but also control the cell elongation, organ differentiation, bud differentiation, flowering, bearing and leaf formation, dormancy, etc. (Amarjit, 2000; Manivannan et al., 2008; Zhao et al., 2010). Some of the plant growth substances can improve the contents of both plant proteins and sugars, and also can enhance their drought resistance, cold tolerance, alkali resistance and ability to resist diseases and insects (Zhang, 2006). Guo et al. (2010) found that spraying plant growth regulators of SA-DTA-6 at different concentrations on the adzuki beans increased the soluble protein and chlorophyll contents and reduced malondialdehyde (MDA) contents effectively. Jiang et al.

(2001) proved that foliar application of multi-effect triazole fertilizers obviously increased the chlorophyll and protein contents, extended the functioning period, improved the photosynthetic efficiency, which is of important significance in increasing crop production and improving crop quality.

To improve the adzuki bean (variety Jihong 8937) yield, we effectively controlled its bloom and pod using bean various kinds of plant growth regulators at different concentrations at different stages, so as to demonstrate the effect of plant growth regulators on the growth, development and yield of adzuki beans.

Materials and methods

Materials

The variety of Jihong 8937 was adopted in this research, which was bred by the Grain and Oil Station of the Agriculture and Forestry Academy of Sciences of Hebei Province, China. For growth retardant, 15% paclobutrazol (PP333) was a product by Jiangsu Jian Brand Pesticide Chemical Industry Company, which is widely used nowadays

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with some effects of dwarf and lodging-resistant on field crops (Gong et al., 2010). For growth promoter, 5% naphthalene acetic acid (NAA), a product by Sichuan Guoguang Chemurgy Co. Ltd. was used in the test.

Methods

This experiment was carried out in the Herbarium Garden, Agricultural University of Hebei, China in 2006. The experimental fields were of loam soil and fertilized in equalization, and the last crop was wheat sowed on July 5th by ditching and bunch planting, spaced at 0.5 m × 0.2 m apart. Each kind of plant growth regulators was formulated with three different concentrations, 90 mg/L (R1 stands for paclobutrazol, A1 stands for naphthalene acetic acid), 180 mg/L (R2 stands for paclobutrazol, A2 stands for naphthalene acetic acid) and 270 mg/L (R3 stands for paclobutrazol, A3 stands for naphthalene acetic acid). As the CK, the same quantity of water was sprayed onto the plant. There were 7 treatments with six replicates, the plot size was 2.5 m × 5 m, and there were 42 plots in total. The experiment plots were arranged randomly, and when bean plants grew to the stage of 6–8 compound leaves, plant growth regulators were sprayed before 11 am or after 4 pm everyday, and a second spray was needed if it rained within 6 hours. The data were collected at the 5th day after spraying with the PGRs, and recorded at 8-day intervals, 6 times in total.

Assay

Chlorophyll contents

The fresh blades with the midrib riddled were cut into pieces and extracted by using 95% ethanol in the dark, (shake some times during the 24 h), and thereafter, they went into colorimetric analysis using the ultraviolet spectrophotometer at the wavelengths of 470 nm, 649 nm and 665 nm, respectively, and setting out the degree of light-absorbency of chlorophyll a, chlorophyll b and carotenoid to calculate their contents (Zhang, 2001).

Soluble protein contents

The fresh templates were ground into homogenate and centrifuged at 3000 r/min for 10 min to get the supernatant,

which was put into a test tube with a plug and fully mixed with Coomassie brilliant blue solution added, laying up for 2 min. The same quantity of water was compared with Coomassie brilliant blue solution at the wavelength of 595 nm for colorimetric analysis, and finally converted to the protein contents according to the CONC data (Zhang, 2001).

Results

Influences of different plant growth regulators on growth rhythm

Table 1 shows the influence of PP333 and NAA treatments on adzuki bean growth. The results indicated that spraying PP333 could shorten the childbearing period while spraying NAA extended childbearing period. In all treatments, there was no obvious difference before branching period, however, during the branching period, different treatments created different lengths of childbearing period, with PP333 treatment shortening the branching period and NAA treatment lengthening the childbearing period. As for their influence on the flower and pod period, PP333 extended it and NAA turned out to be in the contrary. Meanwhile, high concentrated regulators showed obvious effects, but the duration differences of mature period were not significant. Therefore, plant growth regulators mainly changed the branching period and flower and pod period, therefore, it was concluded that the two periods are key to the adzuki beans in the transition from vegetative growth to reproductive growth.

Influences of different plant growth regulators on morphology of mature adzuki beans

Table 2 shows the influences of different plant growth regulators on the morphology of adzuki beans, indicating that spraying PP333 could dwarf the plant height, strengthen the stem, and increase the number of internodes and the branches. For their different concentrations, the medium concentration had the most effective effects, but for the influence on the plant stem, the greater inhibiting effect was obtained with the concentrations. Spraying the NAA could increase the plant height, and the medium concentration treatment showed the most distinct effect. Moreover, NAA could also decrease the number of internodes, and the medium concentration

Table 1 Effects of PP333 and NAA on growing courses of adzuki beans

Stage duration (d)	CK	R1	R2	R3	A1	A2	A3
Whole growing stage	99c	99c	98c	96d	100c	104a	102b
Seedling period	9a	9a	9a	9a	9a	9a	9a
Seedling stage	18a	18a	18a	18a	18a	18a	18a
Branching stage	20c	19c	17d	17d	21c	25a	24b
Flowering and podding stage	25c	27b	29a	26b	27b	27b	25c
Autumn stage	26a	27a	25ab	26a	25ab	25ab	26a

Data are the average of three replicates. Different letters in the same line indicate significant difference at 0.05 level.

Table 2 Effects of PP333 and NAA on plant morphology in mature period

Items	CK	R1	R2	R3	A1	A2	A3
Plant height (cm)	49.0b	46.8c	46.2c	43.2d	52.2a	54.8a	50.4b
Plant cauline width (cm)	0.83bc	0.86b	0.91a	0.83bc	0.80	0.86b	0.82c
Plant cauline burls	20.1b	20.8b	22.1a	20.2b	19.6b	19.9b	18.3c
Plant ramifications	6.1c	6.2c	7.0a	6.6b	6.1c	6.5b	5.9c

Data are the average of three replicates. Different letters in the same line indicate significant difference at 0.05 level.

treatment could also magnify the stem and increase the number of branches.

Influences of different plant growth regulators on aboveground dry matter accumulation

With the treatment of PP333, dry matter accumulation was comparatively low in the early stages, but later the gap was narrowed gradually. With the NAA treatment, during the whole childbearing period, the dry matter accumulation took a priority (Table 3). It was concluded that PP333 treatment could strengthen the plants and increase the accumulation of dry matter aboveground. As for the dry matter accumulation in the flowering and pod period, PP333 treatment brought forward the flowering and pod period. Therefore, the quantity of dry matter accumulation with treatments of R1 and R2 was larger than that with the CK in the whole childbearing period. However, the quantity showed in the treatment R3 was always lower than that in the CK treatment. The reason may be that high concentrations restrained the normal plant growth and development, which shorted the vegetative growth and reduced the quantity of accumulation in the flowering and pod period. Along with the bearing progress, from the 45th day, the quantity with A1 and A2 treatments began to surpass the CK. However, with the treatment of A3, the accumulation was smaller than the CK all the time, which was also caused by the inhibiting effect of NAA at the highest concentration.

Influence of different plant growth regulators on physiologic parameters

Carbon dioxide immobilized enzyme took up 50 percent of soluble proteins and with blade aging, the RuBP carboxylase enzyme was broken down, which was the main reason for decline of photosynthesis in the aging process. Therefore, the change of soluble protein contents was one reliable index reflecting the blade functions and aging extent. Figures 1–4 reveal the influences of PP333 and NAA on the soluble protein and chlorophyll contents. The medium and low concentrations could increase the contents of the soluble protein and chlorophyll, and the improved range of medium concentration did the best for improving the range, while the higher concentration showed an inhibiting effect. Among the different treatments, both the soluble protein and chlorophyll attained the peak on the 28th day and then dropped down rapidly. In the early stages, no evident differences were found and the most evident differences were shown in the middle age, and later the gap was narrowed gradually.

Influence of different plant growth regulators on yield components

As shown in Table 4, both medium and lower concentrations increased the podding number, while the higher concentrations of these two kinds of regulators reduced it slightly, with

Table 3 Effects of different concentrations of PP333 on the dry matter accumulation in aboveground crop

Plant part (g/plant)	Treatments	Days after spraying					
		5 d	13 d	21 d	29 d	37 d	45 d
Aboveground	CK	6.14a	9.83b	16.45b	30.24a	42.29ab	45.12ab
	R1	6.02ab	7.24bc	15.24b	31.42a	40.75ab	47.86a
	R2	5.86b	9.26b	12.81c	25.58b	40.48ab	49.53a
	R3	5.19bc	8.86	14.24b	26.43b	38.75c	43.98ab
	A1	5.41b	12.84a	18.45ab	31.26a	41.98ab	46.87ab
	A2	6.25a	11.18a	19.12a	29.45ab	46.21a	49.82a
	A3	6.13a	9.76b	20.79a	26.85b	43.75a	45.41ab
Flower and pod	CK	–	–	0.75a	2.36a	6.21ab	7.91ab
	R1	–	–	0.64ab	2.58a	7.32a	8.16ab
	R2	–	–	0.76a	2.61a	6.41ab	8.89a
	R3	–	–	0.88a	1.62b	6.24ab	7.42b
	A1	–	–	0.25c	1.83b	5.98b	8.54a
	A2	–	–	0.43bc	1.76b	5.02b	8.18ab
	A3	–	–	0.34c	1.34c	5.86b	7.12b

Each datum in the table is an average of three replicates. Different letters in the same column indicate significant difference at 0.05 level.

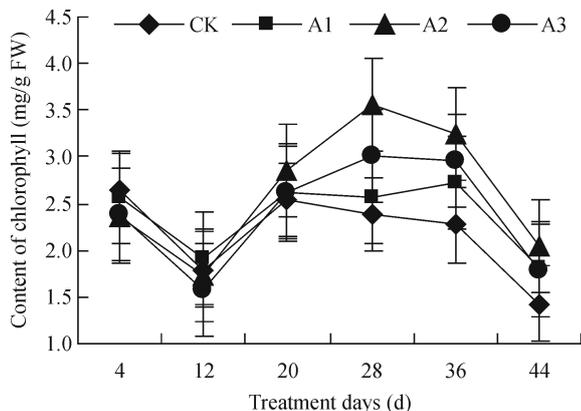


Figure 1 Content of chlorophyll by NAA treatment

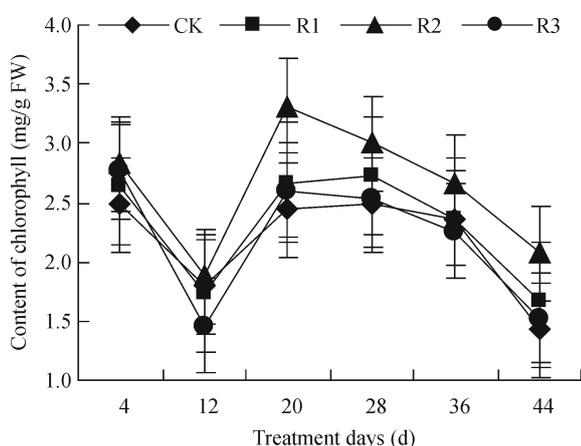


Figure 2 Content of chlorophyll by PP333 treatment

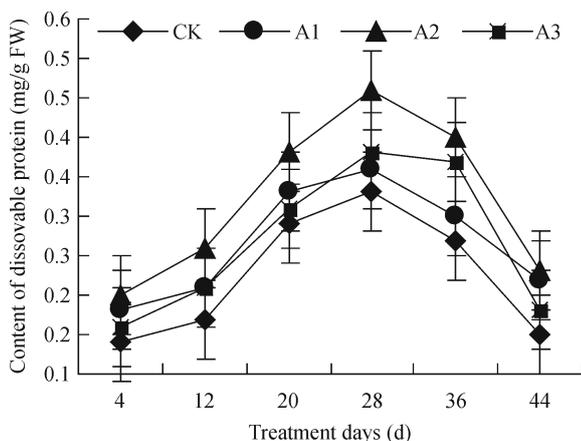


Figure 3 Content of dissolvable protein by NAA treatment

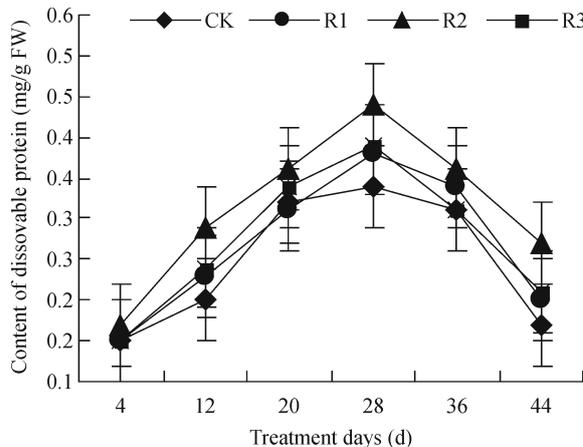


Figure 4 Content of dissolvable protein by PP333 treatment

a tendency of the seeds per pod and seed weight per plant keeping the accordance. For 100-seed weight, all of the treatments produced more than the CK, and treatment R2 did the best which produced 16.13 g, but the diversity was not evident. As for the final production, treatment R1 produced the most, by 10 percent more than the CK. Except for treatments R3 and A3, all the productions of R2, A1 and A2 were higher than the CK, which was caused by the inhibiting of the higher PGR concentrations. It was also found that the appropriate concentration of both regulators could improve the production, and the effect of PP333 treatment was better than NAA.

Discussion

PP333 is an effective plant growth regulator with low toxicity, which can delay the plant growth, restrain the branch extension, strengthen the stem and improve photosynthetic rate. Its main effect is to restrain the vegetative growth to let more assimilated matter get transported to reproductive organs, which would increase production remarkably (Muday et al., 1994; Guo et al., 2004; He et al., 2010). Huang et al. (2008) showed that spraying 15% PP333 could produce 9.05% more than CK. Chen et al. (1996) pointed out that PP333 could not only increase the rice production by about 16%–25% but also improve the content of chlorophyll; Chen et al. (1998) indicated that PP333 treatment could increase the content of protein and chlorophyll of bean; and Li et al. (1995) showed that PP333 could increase the protein content of wheat. Our experiment indicated that PP333

Table 4 The configuration of yields for PP333 and NAA treatment

Items	CK	R1	R2	R3	A1	A2	A3
Seeds per pod	30.8ab	34.2a	33.8a	29.4b	32.1ab	33.3a	29.7b
Seed weight per plant (g)	20.6a	22.4a	22.0a	18.9b	21.5a	22.2a	19.8b
100-seed weight (g)	15.44b	15.61ab	16.13a	15.82ab	15.74	16.01a	15.86ab
Yields (kg/hm ²)	1365.7b	1491.4a	1440.0a	1320.0b	1371.4b	1405.7ab	1337.1b

Each datum in the table is an average of three replicates. Different letters in the same line indicate significant difference at 0.05 level.

treatment at different concentrations could bring forward the flowering period, enhance the reproductive growth and effectively prevent crop excessive growth. The medium and lower concentrations could increase specific leaf weight, the contents of protein and chlorophyll, and the dry weight of flowers. The high concentrations could inhibit them, because PP333, as a Triazole-like growth regulator, could inhibit the compound of endogenesis gibberellin and deduce endogenesis of growth hormones, therefore higher concentrations restrained the plant growth and finally caused the inhibiting effect.

NAA is a growth accelerator, which has a similar physiological action as heteroauxin and is widely applied in the agriculture production, such as improving the completeness of cell membrane, promoting budding and flowering, preventing fruits drop, and regaining the cells fissional ability (Han et al., 1996; Amarjit, 2000). Some researches indicated that spraying NAA had evident influence on plant growth (Mizra et al., 1982; Zhou et al., 2003; Li et al., 2010). Researches showed that spraying NAA on leaves could effectively promote the growth and increase the production. Our experiment indicated that NAA could not only distinctively speed up crop growth, prolong the vegetative period and shorten reproductive stage, but also improve leaf area index. The medium and lower concentrations could increase the content of the soluble protein and chlorophyll, and the main reason may be in that NAA promoted cell division and growth, enlarged the cell and delayed the blade aging, which could benefit the plant growth. Our research also confirmed that the lower and medium concentrations of these PGRs could increase the yield, and the reason might be in that PP333 could make plant shape become reasonable, optimized the development of the reproductive organs and booted the transportation of matter, and thus speeded up crop maturity.

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