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Effect of Spraying Uniconazole on Dry Matter Accumulation and Distribution of Soybean after Blooming

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Abstract: The yield formation of soybean is related closely to the photosynthesis and dry matter accumulation and distribution, out ratio (OR) and contribution ratio (CR) of every organ after blooming. In this study, effects of spraying uniconazole at V5 and R1 stages, respectively, on the LAI, Leaf greenness, dry matter accumulation and distribution of soybean after blooming. OR and CR of every organ were examined to explore the yield forming mechanism. Spraying uniconazole increased LAI and Leaf greeness after blooming, delayed theirs degradation effectively and prolonged leaf longevity. Spraying uniconazole at V5 stage significantly increased dry matter accumulation and the effect of 75 mg/L treatment was the best for Zhechun 3(early-maturing soybean cultivar), the effect of 30 mg/L treatment was the best for Gongxuan1 (late-maturing soybean cultivar). Spraying uniconazole at R1 stage could increase dry matter accumulation and the effect on Zhechun 3 was significantly higher than on the contrast, the best concentration of uniconazole was 100 mg/L, but there was no significant difference between uniconazole treatments for Gongxuan 1 and the contrast. Spraying uniconazole could significantly increase the ratio of dry leaf weight and dry root weight at podding stage and increase the ratio of dry pod weight at maturity. Spraying uniconazole could significantly increase OR and CR of the root and leaf.

Key words: Soybean · Uniconazole · Dry matter accumulation · Dry matter distribution

INTRODUCTION

Relay-planting soybean pattern is dominant in Southern China. However soybean grow flourishing easily in the relay-planting system with corn, soybean yield is lower [1, 2]. Plant growth regulators play an important role in crop production and are being used increasingly to manipulate plant growth and yield [3-5]. Effect of many kinds of plant growth regulators such as uniconazole, paclobutrazol, Mixtalol and Mepiquat Chloride on yield, dry matter accumulation and distribution of crops have been studied and the relationship between the yield and the dry matter accumulation and distribution was positive [6-17]. The effect of uniconazole on soybean yield were reported to increase by 15-18% [18-20], or by 21.26% [21]. Yield of soybean increased by uniconazole may be related with the change of dry matter accumulation and distribution, the out ratio and contribution ratio of vegetative organs, but the effect of uniconazole on dry matter accumulation and distribution of soybean was reported less. Out ratio (OR) and contribution ratio (CR) were the two indexes which showed the ability of matter transporting at podding stage. The former figured the outputting ability of organ storage matter and the latter presented the contribution ability of vegetative organs to seed [22]. But the effect of uniconazole on OR and CR of soybean vegetative organs has not been reported. We studied the effect of spraying different concentrations of uniconazole at V5 and R1 stage on the OR and CR, dynamic rule of dry matter accumulation and distribution for each organ of soybean to explore the physiology characteristic of yield increase of soybean by spraying uniconazole.

MATERIALS AND METHODS

Material and Medicament: Soybean cultivars Zhechun 3 (early-maturing) and Gongxuan 1 (late-maturing) were released in 2006 and 2007, respectively. 5% uniconazole medicament was provided by the Jianhu Pesticide Factory of Jiangsu province. Experimental soil fertility is net nitrogen (N) 3.24 g/kg, P_2O_5 3.12 g/kg, K_2O 1.96 g/kg, organic matter 16.63 g/kg and the pH was 7.

Design of Experiment: The experiments were carried out at the teaching farm of Sichuan Agricultural University in

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2006 and 2007. The experiment was conducted in pot in 2006, with two factors randomized completely block design. Factor A was spraying stage, A1: V5 stage; A2: R1 stage. Factor B was spraying concentration (mg/L) of uniconazole, B0:0, B1: 25, B2: 50, B3: 75, B4: 100. The experiment had 3 replicates; each replicate had 18 pots in every treatment. Five holes were seeded in every pot and four plants were remained after emergence. The size of pot was 36 cm × 26 cm. The distance between two pots was 60 cm. The base fertilizer was urea 30 g/pot, calcium superphosphate 2000 g/pot and potassium chloride 30 g/pot. Top-dressing was urea 30 g/pot at R1 stage. The other management of pot experiment was the same with field production.

The field experiment was conducted by two factors randomized block design in 2007. Factor A was spraying stage, A1: V5 stage; A2: R1 stage; Factor B was spraying concentration (mg/L), B0: 0; B1: 30; B2: 60; B3: 90; B4: 120; B5: 150. The experiment had 3 replicates. The block area was 5 m × 2 m. Soybean was planted in wheat bandwidth after wheat harvested, sowed three rows in every cincture with 30 cm hole spacing. The experiment bandwidth was 2 m, with wheat bandwidth 1.17 m and maize bandwidth 0.83 m. The density was 10^5 plant/ha and the base fertilizer was net N 16.2 kg/ha, P_2O_5 7.2 kg/ha, K_2O 7.2 kg/ha. Top-dressing was net N 16.2 kg/ha at R1 stage. The density of maize is 4.55 × 10^4 plant/ha and the base fertilizer was net N 157.5 kg/ha, P_2O_5 20 kg/ha, K_2O 45 kg/ha and top-dressing was net N 127.5 kg/ha at the bell-mouthed stage. The other management was according to the high yield productivity field of soybean and maize.

Measured Items and Methods

Dry Matter Accumulation: At R3, R5 and R8 stages, we sampled 10 plants from each block, then the plants from the pot experiment were divided into the parts of root, stem, leaf and pod and the plants from the field experiment were divided into the parts of stem, leaf and pod. These organs were dried to constant-weight under 80°C after they were fixed under 105°C for 1h. Then dry matter weights of organs were measured.

Dry Matter Distribution

$$\text{The ratio of each organ dry matter (\%)} = \frac{\text{each organ dry matter}}{\text{total biomass}} \times 100$$

Leaf Greeness: The leaf greenness of the second compound leaf was measured by "SPAD-502" chlorophyll instrument. Beginning at the fifth day after blooming, the leaf greenness was measured every 14d until R6 stage.

LAI: The LAI was measured by "LI-2000" Canopy Analyzer. Beginning at the fifth day after blooming, the LAI was measured every 14d until R6 stage.

Out Ratio and Contribution Ratio

$$\text{Out Ratio (OR)} = \frac{\text{The organ dry matter at R4 stage-The organ dry matter at R8 stage}}{\text{The dry matter accumulation at R4 stage}} \times 100\%$$

$$\text{Contribution Ratio (CR)} = \frac{\text{The organ dry matter at R4 stage-The organ dry matter at R8 stage}}{\text{The pod dry matter at R8 stage}} \times 100\%$$

Statistical Analysis: The data of a block were measured with 9 plants and the average was calculated with 3 replicates for each. All data in this study were expressed as means ± SD. The data were analyzed using one-way analysis of variance and Duncan's multiple range test at the 5% level of significance from the DPS 6.55 package for windows.

RESULTS AND DISCUSSION

Dynamics of LAI: The pattern of LAI change after blooming presented a single apex curve (Fig. 1). The peak of LAI was to be about 33d after blooming (R5 stage). The time of reaching apex was not changed by spraying uniconazole, but LAI after blooming for uniconazole treatments was higher compared with the contrast and the speed of LAI descending after R5 stage for uniconazole treatments was lower than that for the contrast. LAI of B3 treatment at A1, was the highest, that of B2 treatment was the second. LAI of B4 treatment was the highest at A2.

Dynamics of Leaf Greeness after Bloooming: The change of leaf greeness presented a single apex curve after blooming (Fig. 2). The peak of leaf greeness was to be about 33d after blooming (R5 stage). The time of reaching apex was not changed by spraying uniconazole, but the leaf greeness after blooming for uniconazole treatments was higher than that for the contrast and the decreasing speed after R5 stage for uniconazole treatments was lower than that for the contrast. The leaf greeness of B3, B4 and B2 treatments at A1 was still higher at 47d after blooming, which of B4 and B3 treatments at A2 were still higher at 47d after blooming.

Dry Matter Accumulation: The dry matter accumulation at R3 and R5 stages under lower uniconazole concentration treatments at A1 was higher significantly than that for the contrast, which for higher uniconazole concentration treatments was lower contrary (Table 1). It showed that dry matter accumulation of B3 and B4 treatments at A2 were higher than that of the contrast in the pot experiment, while the effect of spraying uniconazole at A2 on dry matter accumulation of the field experiment was not significant. The dry matter accumulation was higher significantly than the contrast at R8 stage by spraying uniconazole concentration between 25 mg/L and 100 mg/L at A1. As far as the dry matter accumulation after R3 stage, uniconazole treatments between 25 mg/L and 100 mg/L at A1 were higher significantly than the contrast for both experiments, uniconazole treatments at A2 were significantly higher than the contrast only for the pot experiment. These indicated that spraying uniconazole concentrations between 25 mg/L and 100 mg/L at A1 was propitious to dry matter accumulation and the effect of spraying uniconazole at A2 was not remarkable until the spraying concentration was higher.

Ratio of Root to Total Biomass (RRTB): RRTB at R3 stage for uniconazole treatments was significantly higher than that for the contrast, but RRTB at R8 stage for uniconazole treatments at A1 was significantly lower than that for the contrast (Table 2). RRTB of B3 treatment at A1 was the highest and higher than that of the contrast by 4.35%. RRTB of B4 treatment at A2 was the highest and higher than that of the contrast by 3.11%. RRTB was lower than the contrast by 0.03%-2.33% at R8 stage under uniconazole treatments at A1, but there was no significant difference of RRTB between uniconazole treatments at A2 and the contrast. The RRTB difference between R3 and R8 stages for uniconazole treatments was significantly higher than that for the contrast and the effect of B3 treatment at A1 was the best and higher than the contrast by 6.22%, the effect of B4 treatment at A2 was the best and higher than the contrast by 3.25%. These showed that spraying uniconazole could promote transportation of the nutriment absorbed by root.

Ratio of Stem to Total Biomass (RSTB): RSTB presented downtrend from R3 to R8 stage. The RSTB for uniconazole treatments at A1 was significantly lower than that for the contrast at R3 and R8 stages for both experiments, as the concentration increased, the RSTB decreased (Table 3). But the RSTB for uniconazole treatments at A2 was significantly lower than that for the contrast only for pot experiment. The RSTB decease from R3 to R8 stage for uniconazole treatments was significantly higher than that for the contrast only for field experiment.

Ratio of Leaf to Total Biomass (RLTB): RLTB presented downtrend from R3 to R8 stage (Table 4). The RLTB under uniconazole treatments was significantly higher than that for the contrast at R3 stage. RLTB for uniconazole treatments at A1 was higher significantly than that for the contrast at R3 and R8 stages for both experiments, as the concentration increased, the effect increased. RLTB at R3 stage under uniconazole treatments at A2 was significantly higher than that for the contrast only for pot experiment. RLTB at R8 stage was significantly lower than the contrast by spraying the concentration from 25 to 100 mg/L at A1 only for the field experiment. The difference between RLTB at R3 stage and RLTB at R8 stage for uniconazole treatments was significantly higher than that for the contrast. These indicated that spraying uniconazole was propitious to leaves assimilation transportation and the effect was not significant until the spraying concentration was higher at A2 especially in relay-cropping environment.

Ratio of Pod to Total Biomass (RPTB): RPTB presented ascending trend from R3 to R8 stage and the raising speed after R3 stage was higher than the contrast under uniconazole treatments for both experiments (Table 5). RPTB for uniconazole treatments at A1 was significantly lower than that for the contrast at R3 stage, as concentration increased, RPTB decreased. RPTB for uniconazole treatments at A2 was significantly lower than that for the contrast at R3 stage only for the pot experiment. RPTB for uniconazole treatments at A1 and higher concentration uniconazole treatments at A2 was significantly higher than that for the contrast at R8 stage. The difference between RPTB at R3 stage and RPTB at R8 stage for uniconazole treatments at A1 for both experiments, uniconazole treatments at A2 only for the pot experiment and B5 treatment at A2 for field experiment was significantly higher than that for the contrast. These

Table 1: Effect of spraying uniconazole on dry matter accumulation at different growth stages (g/plant)

	R3		R5		R8		Dry matter accumulation after R3	
Treatment	2006	2007	2006	2007	2006	2007	2006	2007
A1B0	9.85cd	38.18bc	12.26c	52.87de	23.60f	90.25d	13.75e	52.07d
A1B1	10.17bc	40.53a	12.53bc	63.64a	26.64c	107.85a	16.47c	67.32a
A1B2	10.52a	38.91b	12.68b	59.50b	28.59b	103.27b	18.06a	64.36b
A1B3	10.57a	38.74bc	13.39a	54.20c	29.56a	99.45c	18.99b	60.71c
A1B4	9.53df	36.88de	11.47d	53.06d	25.08de	90.22d	15.55d	53.35d
A1B5		36.55e		49.55f		76.68e		40.13e
A2B0	9.85cd	38.18bc	12.26c	52.87de	23.60f	90.25d	13.75e	52.07d
A2B1	10.06c	37.74cd	12.28c	52.46e	24.71e	90.87d	14.65de	53.13d
A2B2	10.18bc	38.12bc	12.34c	52.72de	25.46de	90.96d	15.28d	52.85d
A2B3	10.41ab	38.30bc	12.66b	52.83de	25.78d	90.85d	15.37d	52.54d
A2B4	10.48ab	38.93b	12.71b	52.98d	27.34c	91.28d	16.86c	52.35d
A2B5		39.00b		53.01d		91.87d		52.87d

Note: Values within column followed by a different letter are significantly different at 5% level of probability. A was spraying stage, A1: V5 stage; A2: R1 stage. B was spraying concentration (mg/L) of uniconazole, 2006(B0:0, B1: 25, B2: 50, B3: 75, B4: 100), 2007(B0:0, B1: 30, B2: 60, B3: 90, B4: 120, B5: 150) The same below

Table 2: Effect of spraying uniconazole on RRTB at different growth stages (%)

Treatment	R3	R8	Reduction percentage in RRTB after R3
A1B0	23.53c	7.44a	16.09e
A1B1	26.56ab	7.41a	19.15cd
A1B2	26.69ab	6.75b	19.94bc
A1B3	27.88a	5.57c	22.31a
A1B4	26.01b	5.11c	20.90ab
A2B0	23.54c	7.44a	16.10e
A2B1	25.63b	7.43a	18.19d
A2B2	25.72b	7.37a	18.35d
A2B3	26.49ab	7.37a	19.12cd
A2B4	26.65ab	7.29a	19.35cd

indicated that spraying uniconazole was propitious to pod assimilation accumulation and the effect of spraying uniconazole at A2 was not significant until the concentration was higher in relay-cropping environment.

Dry Matter Transportation: The size order for out ratio (OR) and contribution ratio (CR) of vegetative organs was leaf □ root □ stem (Table 6). The OR and CR of root and leaf were increased significantly under uniconazole treatments, as the concentration increased, the effect increased and the effect of spraying uniconazole at A1 was higher than that of spraying uniconazole at A2. But the OR and CR of stem were decreased a little under uniconazole treatments.

The effects of uniconazole on soybean yield were reported, but the research about the dry matter accumulation and distribution was less. Zhou *et al.* [14] studied the effect of uniconazole on vigorous seedling growth and seed yield of rape, which indicated that the dry matter accumulation and seed yield were increased significantly by spraying uniconazole. Chen *et al.* [19] studied the relation between dry matter accumulation and spraying uniconazole at R1 stage under net cropping, which indicated that the dry matter accumulation was increased significantly by spraying uniconazole. They were the same as the result of our study. This study also indicated that there were positive correlations between RPTB and dry matter accumulation and distribution. The dry matter accumulation at R8 stage was higher than the contrast by 6.27%-25.28% by spraying the concentrations from 25 mg/L to 100 mg/L uniconazole at V5 stage. The effect of 75 mg/L and 50 mg/L treatments at V5 stage were better for pot experiment and the effect of 30 mg/L treatment at V5 stage was the best for field experiment.

Table 3: Effect of spraying uniconazole on RSTB at different growth stages (%)

	R3		R8		Reduction percentage in RSTB after R3	
Treatment	2006	2007	2006	2007	2006	2007
A1B0	28.29a	55.05a	9.58a	38.30a	18.71a	16.76e
A1B1	26.73bc	52.96cd	8.37c	32.20bcd	18.36a	20.77bcd
A1B2	26.16cd	52.70de	7.37d	31.69cd	18.79a	21.02bcd
A1B3	23.51e	51.93e	6.32e	26.30d	17.19b	25.63a
A1B4	25.89cd	50.96f	7.52d	27.70a	18.37a	23.26ab
A1B5	--	50.00g	--	27.64d	--	22.35abc
A2B0	28.29a	55.06a	9.58a	38.30a	18.71a	16.76e
A2B1	28.02ab	52.62de	9.49a	36.75abc	18.54a	15.88e
A2B2	27.57ab	53.89bc	9.10b	38.11a	18.47a	15.77e
A2B3	26.80bc	52.99cd	8.51c	37.24ab	18.29a	15.75e
A2B4	25.13d	53.83bc	8.44c	35.51abc	16.69b	18.32de
A2B5	--	54.21ab	--	35.09abc	--	19.12cde

Table 4: Effect of spraying uniconazole on RLTB at different growth stages (%)

	R3		R8		Reduction percentage in RSTB after R3	
Treatment	2006	2007	2006	2007	2006	2007
A1B0	31.91e	44.45f	0.54a	8.36c	31.37e	36.09e
A1B1	38.01b	46.69d	0.50a	6.34d	37.51b	40.35a
A1B2	38.99b	47.02d	0.43a	7.74c	38.56b	39.28ab
A1B3	46.49a	47.76c	0.34a	8.31c	46.14a	39.45ab
A1B4	47.19a	48.85b	0.45a	9.71b	46.75a	39.14b
A1B5	--	49.81a	--	11.12a	--	38.69b
A2B0	31.91e	44.45f	0.54a	8.36c	31.37e	36.09e
A2B1	35.45d	46.91d	0.54a	8.15c	34.91d	38.76b
A2B2	36.74c	45.64e	0.53a	8.19c	36.21c	37.44cd
A2B3	38.08b	46.70d	0.49a	8.25c	37.59b	38.45bc
A2B4	38.54b	45.81fe	0.42a	8.30c	38.12b	37.51cd
A2B5	--	45.40e	--	8.35c	--	37.05de

Table 5: Effect of spraying uniconazole on RPTB at different growth stages (%)

	R3		R8		Reduction percentage in RSTB after R3	
Treatment	2006	2007	2006	2007	2006	2007
A1B0	16.27a	0.50a	82.44f	53.35d	66.17d	52.85d
A1B1	8.70b	0.34cd	83.73d	61.46b	75.03bc	61.11b
A1B2	8.15b	0.28f	85.44c	60.58b	77.29b	60.30b
A1B3	2.13c	0.31de	87.77a	65.39a	85.64a	65.08a
A1B4	0.97c	0.19g	86.92b	62.59b	85.95a	62.40ab
A1B5	--	0.19g	--	61.23b	--	61.04b
A2B0	16.26a	0.50a	82.44f	53.35d	66.18d	52.85d
A2B1	10.90b	0.47a	82.54f	55.10cd	71.64c	54.64cd
A2B2	9.97b	0.47a	83.00ef	53.69cd	73.03c	53.21cd
A2B3	8.63b	0.31ef	83.63de	54.51cd	75.00bc	54.21cd
A2B4	9.69b	0.36bc	83.85d	56.19cd	74.16bc	55.83cd
A2B5	--	0.39b	--	56.56c	--	56.18c

The dry matter accumulation for uniconazole treatments at R1 stage was significantly more than that for the contrast only for the pot experiment and for the field experiment the higher concentration of spraying uniconazole at this stage should be needed to reach the effect.

The RRTB and RLTB for uniconazole treatments were significantly higher than that for the contrast at podding and grain filling stage. These indicated that nutriment was more stored in root and leaf of uniconazole treatment plants. The related analysis indicated that there were the positive correlations between the RPTB and RLTB, RRTB, dry matter accumulation at maturity and the correlation coefficient was 0.9**, 0.54 and 0.68*, respectively.

The canopy leaf area is usually described by the leaf area index (LAI), the size of LAI could show the ability of capturing the radiation and photosynthesis of the plant colony to some extent [22]. Leaf greeness could show the relative content of leaf chlorophyll. The chlorophyll content of the function leaf was not only related to the leaf color, but also had the direct influence on photosynthesis [24-26]. Total chlorophyll had high

Table 6: Effect of spraying uniconazole on OR and CR

Treatment	Root weight difference (g/plant)	Root OR (%)	Root CR (%)	Leaf weight difference (g/plant)	Leaf OR (%)	Leaf CR (%)	Stem weight difference (g/plant)	Stem OR (%)	Stem CR (%)
A1B0	0.56d	5.70c	2.89d	3.01h	30.61e	15.48e	0.52bc	5.34ab	2.68a
A1B1	0.73c	7.16b	3.27cd	3.73e	36.71b	16.72d	0.49c	4.82b	2.19b
A1B2	0.88b	8.34b	3.60bc	3.97c	37.82b	16.27de	0.64a	6.11a	2.62ab
A1B3	1.30a	12.30a	5.02a	4.81a	45.53a	18.53b	0.62a	5.84a	2.38ab
A1B4	1.20a	12.55a	5.49a	4.38b	46.02a	20.10a	0.58ab	6.08a	2.65ab
A2B0	0.56d	5.71c	2.89d	3.01h	30.61e	15.48e	0.52bc	5.34ab	2.68a
A2B1	0.74c	7.37b	3.64bc	3.43g	34.12d	16.80d	0.47c	4.65b	2.28ab
A2B2	0.74c	7.29b	3.51bc	3.60f	35.41c	17.04cd	0.49c	4.80b	2.31ab
A2B3	0.86b	8.22b	3.98b	3.83d	36.87b	17.75c	0.59ab	5.68a	2.73a
A2B4	0.80c	7.61b	3.47bc	3.91c	37.44b	17.07cd	0.32d	3.09c	1.39c

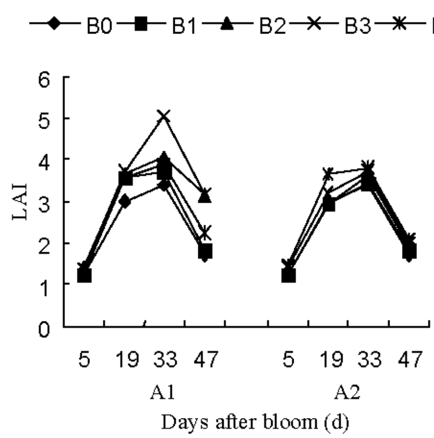

Fig. 1: Effect of spraying uniconazole on LAI

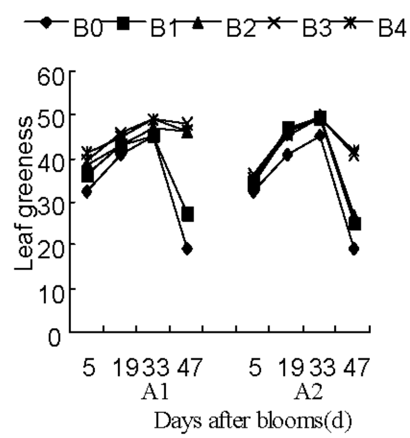

Fig. 2: Effect of spraying uniconazole on leaf greenness

correlated response and relative selection efficiency values for grain yield indicating the effectiveness of chlorophyll in increasing yield [27]. The study of alleviation of flooding damage in winter rape by uniconazole application indicated that pretreatment of seedlings with uniconazole could effectively delay degradation of chlorophyll of rape [4, 28-30]. Which was the same as the result of our study. In this study,.it was obvious that the LAI was bigger, degradation speed of leaf greenness was lower (Fig. 1 and 2), photosynthesis was higher and yield was more (Table 1) by spraying uniconazole, which were propitious to the increase of RPTB and yield consequently.

The OR and CR of root and leaf for uniconazole treatments were higher than that for the contrast, the contribution of leaf and root for uniconazole treatments to pod was higher and the transportation ability was better. The transportation ability of stored matter in stem was lower and outputting was less, which was beneficial to ensure the stem quality and the nutriment of leaf and root transporting. This was the same as the result of the related analysis. So the function of leaf and root showed the yield to some extent on the base of better comprehensive characters. The OR and CR of stem reflected the ability of plant transportation and lodging resistance to some extent, so it could be regarded as the important physiological index of soybean growth.

This study showed that the CR was only equal to 50% of the OR under each treatment and mostly matter was wasted on the process of transportation to pod.

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