Effects of Paclobutrazol on Dry Matter Distribution and Yield in Peanut

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Abstract: Paclobutrazol (PB), an inhibitor of endogenous gibberellin synthesis, was applied to peanut plants altered dry-matter distribution and increased seed yield. PB solution at a concentration of 100, 200 or 400 ppm was sprayed on foliage at the beginning of the pod formation stage (BPFS), the early pod filling stage (EPFS) and the middle pod filling stage (MPFS). The height of the plants treated with PB at BPFS and EPFS was shorter than that of the control plants by more than 10 and 5 cm, respectively. The pod number of the plants treated with 100 or 200 ppm PB at any developmental stage was higher than that of the plants treated with 0 or 400 ppm PB. The seed yield was increased by PB applied at any stage, and the yield after the treatment with 100 or 200 ppm PB at BPFS or EPFS was approximately 370 g m⁻².

Key words: Arachis hypogaea L., Dry matter distribution, Paclobutrazol, Peanut, Seed yield.

Duncan et al. (1978) suggested that partitioning more daily assimilate to fruit is effective to improve peanut yield. Aboagye et al. (1994) found negative correlations between leaf area index and net assimilation rate, suggesting that mutual shading decreased crop production in peanut. One of the prohibitive factors for increasing harvest index in peanut may be excessive dry-matter distribution to stem (Maeda, 1993). In addition, excessive vegetative growth tended to increase disease incidence and to decrease harvest efficiency (Gorbet and Rhoads, 1975). Alteration of the distribution pattern of assimilate may therefore be one of the most important factors to increase yield and improve management of peanut.

Several plant growth regulators (PGRs) have been used for peanut (Wynne et al., 1974; Wu and Santelmann, 1977; Gardner, 1988; Mitchem et al., 1995; Mitchem et al., 1996; York et al., 1996). However, there are only a few reports that showed any increase of yield by the treatment with PGRs (Brown et al., 1973; Gorbet and Rhoads, 1975). Paclobutrazol (PB), a growth regulator that inhibits the synthesis of endogenous gibberellin, has been used to reduce lodging in rice (Ito and Mori, 1987) and to increase the yield in tomato (Berova et al., 2000). Isoda et al. (1999) applied PB to peanut, and demonstrated an increased distribution of assimilates to seeds. In this paper therefore, we examined the effect of the timing of the application and the concentration of PB solution, on the dry-matter distribution and seed yield and also to the effect of PB application on morphological and physiological characteristics in peanut.

Materials and Methods

The experiment was conducted at the experimental farm of Faculty of Horticulture, Chiba University in 1998. The cultivar used here was cv. Nakateyutaka, which is a derivative from the cross between virginia and spanish types and is one of the leading cultivars in Japan. The seeds were sown in paper pots on 15 May. The seedlings were transplanted to the field at 60 cm row width and 20 cm between plants on 28 May, in order to reduce differences among individuals as compared with direct seeding. Fertilizer of N, P₂O₅ and K₂O at 30, 100 and 100 kg ha⁻¹, respectively, was applied just before transplanting. The experimental design was a split plot with two replications; the timing of the PB treatment as the main plot, and the concentration of the PB solution as the sub-plot. Each plot consisted of 6 rows with 5.2 m in length. The water solution of PB at 0, 100, 200 or 400 ppm was sprayed on foliage on 28 July (beginning of pod formation stage: BPFS), 10 Aug. (early pod filling stage: EPFS) or 24 Aug. (middle pod filling stage: MPFS). Bonzaifuroaburu (Nichino Inc.) containing 2% PB was used to prepare each PB solution, and 154 mL m⁻² solution was sprayed for each plot.

Eight plants from the center of the plot were harvested from 28 July at 2-week intervals. Dry weights of leaves, stems, roots and pods were measured after oven drying for 48 h at 80 C. The leaf area was measured with a leaf area meter (AAM-8, Hayashidenko Ltd.). Chlorophyll contents of leaves were also assessed from the SPAD value measured with a SPAD meter (SPAD-502, Minolta Ltd.) at 1-week intervals. Photosynthetic rates

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Abbreviations: BPFS, the beginning of the pod formation stage; CGR, crop growth rate; EPFS, the early pod filling stage; LAI, leaf area index; MPFS, the middle pod filling stage; NAR, net assimilation rate; PB, paclobutrazol; Period I, 1, 2, 2nd week, 2nd to 4th week after the PB treatment, respectively; PGRs, plant growth regulators.
Results

1. Dry-matter accumulation

Fig. 1 shows dry-matter accumulation of each organ. The most effective PB application stage for dry weight increase was BPFS, followed by EPFS. Application of PB at 100 or 200 ppm at BPFS markedly increased pod dry weight, followed by that at 400 ppm. The total dry weight was increased by the increase in pod dry weight and not leaf dry weight. PB applied at 100, 200 or 400 ppm at EPFS also increased the pod dry weight compared with the control, but that applied at MPFS did not. There was no significant difference among the patterns of dry-matter accumulation in the control plants sprayed with water (0 ppm PB) at three different stages, although the pattern in the plants sprayed with water at BPFS was a little different.

2. Morphological characteristics

Table 1 shows morphological characteristics on 6 Sept. (2 weeks after MPFS). The height of the plants treated with PB at BPFS or EPFS was shorter than that of the control plants by more than 10 and 5 cm, respectively. PB applied at MPFS did not affect the plant height because the height was already near the maximum at the time of application. The number of nodes on the main stem, leaf area index (LAI) and the number of primary branches were not influenced by the stage of application and the concentration of PB solution. The number of secondary branches was increased by PB applied at BPFS or EPFS, and the plants treated with 200 ppm PB at BPFS had 10 more branches than the control plants.

3. SPAD values, photosynthetic rates and growth parameters

Chlorophyll content (SPAD value) of the leaves of the uppermost layer adversely correlated with the plant height (Tables 1 and 2). The SPAD values of the plants treated with PB at BPFS or EPFS increased soon after the treatment and attained a peak three weeks after the treatment, but that of the plants treated with PB at MPFS increased only slightly after the treatment (Table 2). PB applied at BPFS affected neither the crop growth rate (CGR) nor the net assimilation rate (NAR) during the 2nd week (Period 1) and the 2nd to 4th week (Period 2) after the PB treatment (Table 3). However, PB applied at EPFS greatly increased CGR and NAR during Period 1, and PB applied at MPFS markedly reduced these values. Concentration dependence of the effect of PB on CGR and NAR was not significant during both periods. The pod growth rate during Period 2 was greatly increased by 100 or 200 ppm PB applied at BPFS or EPFS but was increased only slightly or not increased by 400 ppm PB applied at the same stage. CGR and NAR during Period 1 were significantly influenced by the stage of PB application, but those during Period 2 were not. The pod growth rate during either Period 1 or 2 was not influenced by the stage of PB application.
Table 1. Morphological characteristics on 6 Sept.

| Treated stage | Concentration (ppm) | Plant height (cm) | Node number of main stem | LAI | No. of Primary branches (plant⁻¹) | No. of Secondary branches (plant⁻¹) |
|---------------|---------------------|-------------------|--------------------------|-----|-----------------------------------|-------------------------------------|
|               |                     |                   |                          |     |                                   |                                     |
| BPFS          | 0 ppm               | 38.0              | 22.5                     | 3.2 | 8.0                               | 17.8                                |
|               | 100 ppm             | 26.5              | 21.7                     | 3.2 | 9.8                               | 24.2                                |
|               | 200 ppm             | 26.6              | 21.5                     | 3.2 | 10.8                              | 27.6                                |
|               | 400 ppm             | 26.0              | 21.7                     | 3.2 | 10.0                              | 21.0                                |
| EPFS          | 0 ppm               | 38.8              | 21.4                     | 3.7 | 9.4                               | 20.6                                |
|               | 100 ppm             | 37.8              | 21.9                     | 4.0 | 10.0                              | 26.8                                |
|               | 200 ppm             | 31.2              | 21.1                     | 3.5 | 9.4                               | 22.4                                |
|               | 400 ppm             | 31.1              | 20.9                     | 3.3 | 8.6                               | 20.0                                |
| MPFS          | 0 ppm               | 39.0              | 21.3                     | 4.0 | 9.0                               | 20.6                                |
|               | 100 ppm             | 38.4              | 21.1                     | 3.4 | 8.6                               | 22.2                                |
|               | 200 ppm             | 38.9              | 21.1                     | 3.1 | 9.0                               | 20.2                                |
|               | 400 ppm             | 37.5              | 21.3                     | 3.1 | 8.8                               | 20.2                                |

Significance: Concentration (C) ** ns ns ns **  Treated stage (T ) ** ns ns ns ** Interaction (C X T) ** ns ns ns * 

LAI: leaf area index. BPFS: beginning of pod formation stage. EPFS: early pod filling stage. MPFS: middle pod filling stage. *, **, ns Significant at 5% level, 1% level, not significant.

| Treated stage | Concentration (ppm) | SPAD value 1st wk | SPAD value 3rd wk | Photosynthetic rate 1st wk (µmol m⁻² s⁻¹) |
|---------------|---------------------|-------------------|-------------------|------------------------------------------|
|               |                     |                   |                   |                                          |
| BPFS          | 0 ppm               | 41.8              | 35.6              | 15.0                                     |
|               | 100 ppm             | 46.9              | 72.8              | 15.9                                     |
|               | 200 ppm             | 47.5              | 73.9              | 12.9                                     |
|               | 400 ppm             | 47.2              | 74.4              | 15.8                                     |
| EPFS          | 0 ppm               | 34.3              | 31.4              | -#                                       |
|               | 100 ppm             | 52.4              | 50.7              | -#                                       |
|               | 200 ppm             | 53.3              | 60.6              | -#                                       |
|               | 400 ppm             | 53.9              | 62.3              | -#                                       |
| MPFS          | 0 ppm               | 30.8              | 33.8              | -#                                       |
|               | 100 ppm             | 31.0              | 35.1              | -#                                       |
|               | 200 ppm             | 31.2              | 36.0              | -#                                       |
|               | 400 ppm             | 34.7              | 38.8              | -#                                       |

Significance: Concentration (C) ** ns ns ns **  Treated stage (T ) ** ns ns ns ** Interaction (C X T) ** ns ns ns * 

PBFS: beginning of pod formation stage. EPFS: early pod filling stage. MPFS: middle pod filling stage. **, ns Significant at 5% level, 1% level, not significant. # Data were not taken.

4. Yield and yield components

Pod number was increased by applying 100 or 200 ppm PB at either stage, though not significantly (Table 4). It was higher when PB was applied at EPFS than at BPFS or MPFS. Seed number was increased by applying PB, particularly at 100 or 200 ppm, at BPFS or EPFS, but was not significantly influenced by PB applied at MPFS (Table 4). The mean seed weight was not influenced by PB application. Pod weight was significantly increased by applying 100, 200 or 400 ppm PB at BPFS or EPFS. It was more than 530 g m⁻² when 100 or 200 ppm PB was applied at EPFS, and was about 510 g m⁻² when 400 ppm PB was applied at the same stage. Seed weight (g m⁻²) was also increased by PB applied at any stage. Especially 100 or 200 ppm PB applied at BPFS or EPFS increased the seed yield up to about 370 g m⁻² (Table 4).

Discussion

The effects of many PGRs on peanut have been studied. However, clear results have not been obtained including the effect on yield (Wynne et al., 1974; Wu and Santelmann, 1977; Johnson et al., 1992; Mitchem et al., 1995; York et al., 1996) and often the results differed with the year (Brown et al., 1973; Mitchem et al., 1996). The main objective of these studies was to control excessive shoot growth and not to investigate the seed yield directly. The vine growth was suppressed but the yield was increased by the growth regulator, though the reasons for increased yield were not analyzed in detail (Gorbet and Rhoads, 1975). In the present experiment, the ratio of dry weight of pods to that of stem increased without a large change in leaf area indicating that the treatment altered the distribution of dry-matter from the stem to the pods. The plants treated with PB might be similar to one of the ideotypes described by Duncan et al. (1978) and Maeda (1993) with regard to the restraint of dry-matter distribution to stems.

PB application did not increase the photosynthetic rates at the 1st week after the treatment. In another
experiment, we observed that PB application significantly increased photosynthetic rate at the 3rd week after the treatment (Senoo et al., 2001). The increase in chlorophyll content at the 3rd week after the treatment in the present experiment might therefore be correlated with the increase in the photosynthetic rates during the pod filling period. However, PB application did not significantly increase CGR and NAR at the 2nd to 4th week after the treatment, though it increased the pod growth rate significantly. Therefore, the increase in the photosynthetic rate due to increased chlorophyll content might not have a large effect on dry-matter production.
Thus, it is assumed that the increase in seed yield largely depended on the alteration of dry-matter distribution to seeds due to the suppression of stem elongation, rather than the increase in photosynthetic potential.

Isoda et al. (1999) found that seed yield was increased by PB treatment, though not so much as in this experiment. They applied PB one week later than EPFS, which was the most effective stage of PB treatment in this experiment. The treatment given two weeks later (MPFS) neither increased seed yield nor markedly altered dry-matter distribution. The time of application of paclobutrazol appears to be critical for altering dry-matter distribution and increases seed yield.

PB has a possibility to increase peanut yield. From the studies on the yield components, PB is considered to increase seed yield mainly by increasing the numbers of the pods and seeds. The percentage of early blooming flowers produce mature seeds might be increased by PB treatment. In future research, we will examine the effect of the PB on the flowering and seed-setting habitats.

References

Aboagye, L.M., Isoda, A., Nojima, H., Takasaki, Y., Yoshimura, T., and Ishikawa, T. 1994. Plant type and dry matter production in peanut (Arachis hypogaea L.) cultivars. I. Varietal differences in dry matter production. Jpn. J. Crop Sci. 63: 289-297.

Berova, M. and Zlatev, Z. 2000. Physiological response and yield of paclobutrazol treated tomato plant (Lycopersicon esculentum Mill.). Plant Growth Regul. 30: 177-183.

Brown, R.H., Ethredge, W.J. and King, J.W. 1973. Influence of succinic acid 2,2-dimethylhydrazide on yield and morphological characteristics of starr peanuts (Arachis hypogaea L.). Crop Sci. 13: 507-510.

Duncan, W.G., McCloud, D.E., McGraw, R.L. and Boote, K.J. 1978. Physiological aspects of peanut yield improvement. Crop Sci. 18: 1015-1020.

Gardner, F.P. 1988. Growth and partitioning in peanut as influenced by gibberellic acid and daminozide. Agron. J. 80: 159-163.

Gorbet, D.W. and Rhoads, F.M. 1975. Response of two peanut cultivars to irrigation and kylar. Agron. J. 67: 373-376.

Isoda, A., Nakazato, H., Nojima, H. and Takasaki, Y. 1999. Effects of paclobutrazol on dry matter distribution and canopy structure in peanut. Tech. Bull. Fac. Hort. Chiba Univ. 53: 1-6.

Ito, O. and Mori, Y. 1987. Utilization of triazole-type growth retardants for regulation of lodging in rice plants. Chem. Regul. Plants 22: 159-165.

Johnson, W. C. III, Mullinix, Jr. B. G. and Brown, S. M. 1992. Phytotoxicity of chlorimuron and tank mixtures on peanut (Arachis hypogaea). Weed Tech. 6: 404-408.

Maeda, K. 1993. Groundnut ideotype: Its agro-physiological characteristics and contribution of subsp. fastigiate. Jpn. J. Crop Sci. 62: 211-221.

Mitchem, W.E., York, A.C. and Batts, R.B. 1995. Evaluation of chlorimuron as a growth regulator for peanut. Peanut Sci. 22: 62-66.

Mitchem, W.E., York, A.C. and Batts, R.B. 1996. Peanut response to prohexadione calcium, a new plant growth regulator. Peanut Sci. 23: 1-9.

Senoo, S., Isoda, A., Nojima, H., and Takasaki, Y. 2001. Effects of Paclobutrazol on flowering and seed-setting habit and physiological, morphological characters in peanut. Jpn. J. Crop Sci. 70 (Extra. 1): 188-189.

Wu, C.H. and Santelmann, P.W. 1977. Influence of six plant growth regulators on spanish peanuts. Agron. J. 69: 521-522.

Wynne, J.C., Baker Jr., W.R. and Rice, P.W. 1974. Effects of spacing and a growth regulator, Kylar, on size and yield of fruit of Virginia-type peanut cultivars. Agron. J. 66: 192-194.

York, A.C., Batts, R.B. and Culpepper, A.S. 1996. Response of peanut to PGR-IV™ growth regulator. Peanut Sci. 23: 54-57.

*In Japanese with English abstract.

**In Japanese.