Effects of Paclobutrazol on Podding and Photosynthetic Characteristics in Peanut

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Abstract: The effects of paclobutrazol (PB) on podding habits and photosynthetic characteristics (CO\textsubscript{2} assimilation rate, quantum yield of photosystem II ($\Phi_{\text{PSII}}$) and chlorophyll content) were examined in peanut. Application of PB at the start of the pod formation stage increased the percentage of podding, particularly in early-blooming flowers and seed yield. The major factor for this effect may be an acceleration of dry matter distribution to the early-bearing pods, which resulted from the inhibition of stem growth by PB. Application of PB at the early pod-formation stage increased chlorophyll content and $\Phi_{\text{PSII}}$, resulting in enhanced CO\textsubscript{2} assimilation rates. In the long term, PB tended to increase crop growth rate and net assimilation rate though not significantly. The effects of PB on the photosynthetic characteristics, however, were observed only during a short period at a restricted growing stage, suggesting that an increase in the photosynthetic rate would not be the main factor for the PB-induced increase in seed yield.

Key words: *Arachis hypogaea* L., Chlorophyll content, CO\textsubscript{2} assimilation rate, Paclobutrazol, Percentage of podding, Quantum yield of photosystem II, Yield.

Previously, we reported that the treatment with paclobutrazol (PB, inhibitor of the synthesis of endogenous gibberellin) increased seed yield in peanut (*Arachis hypogaea* L.) by about 20% (Senoo and Isoda, 2003). Application of PB by a foliar spray altered the dry matter distribution, leading to an increase in pods and seeds. In general, a peanut plant bears more than 300 flowers during a period of 2.5 to 3 months flowering period, but only about 15% of them produce seeds (Lim and Gumpil, 1984; Suzuki et al., 1987). It has also been reported that the percentage of podding varied with the soil condition such as moisture and calcium contents. (Coolbear, 1994). In the present study, we examined the effect of PB on podding habits. Because PB changed the leaf color into deep green and increased chlorophyll contents of leaves (Senoo and Isoda, 2003), we also investigated the effects of PB on the characteristics related to photosynthesis, i.e., chlorophyll content, CO\textsubscript{2} assimilation rate, quantum yield of photosystem II ($\Phi_{\text{PSII}}$) and dry matter production.

Materials and Methods

The experiment was conducted at the experimental farm of Faculty of Horticulture, Chiba University in 2000. Fertilizer at the ratio of 30 : 100 : 100 kg ha\textsuperscript{-1} of N, P\textsubscript{2}O\textsubscript{5} and K\textsubscript{2}O was applied just before sowing. The peanut cultivar Nakateyutaka, which is a derivative from the cross between Virginia and Spanish types and one of the leading cultivars in Japan, was used seeds were sown at 60 cm interrow space and 20 cm between plants on 11 May. The plants in the two plots each consisting of 14 rows with 6.4 m length were treated with 150 mL per m\textsuperscript{2} of 200 ppm PB per plot (foliar spray) on 3 Aug. (the early pod filling and the end of fruitful flowering stage). The control plants in the two plots with the same area were not sprayed.

From 22 June to 16 Aug. (during the flowering period), the number of flowers on 10 plants per plot was counted every day and marked with vinyl-coated wires, with a different color for each wk. Yield and yield components of all the marked plants were measured on 27 Sept. Plant height, leaf number and chlorophyll content were measured every wk after the treatment with PB. Eight plants were sampled at 2 wk intervals from 3 Aug. Leaf, stem, root and pod dry weights were determined after oven drying for 48 h at 80°C. Leaf area of the representative plants was measured by an area meter (AMM-8, Hayashidenko Ltd.). The CO\textsubscript{2} assimilation rate and quantum yield of photosystem II ($\Phi_{\text{PSII}}$) of 12 leaflets per plot from the uppermost layer of the canopy were measured from 10 a.m. to 2 p.m. on 21 to 24 Aug. with a CO\textsubscript{2} gas analyzer (CI-301, CID Ltd.) and a portable fluorometer (PAM -2000, Heinz Walz GmbH Ltd.), respectively. Chlorophyll contents were measured with a SPAD meter (SPAD-502, Minolta Ltd.) for 5 plants per plot on 24 and 31 Aug.

Results

1. Number of flowers blooming each wk during the flowering period and their podding percentages

The number of flowers blooming within a wk increased with the delay of blooming time until the 5th wk of the flowering period in both plants with and without...
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Flowering period (22 June - 16 Aug.)
1st wk: 22 June
2nd wk: 29 June - 5 July
3rd wk: 6 - 12 July
4th wk: 13 - 19 July
5th wk: 20 - 26 July

Fig. 1. The number of flowers blooming each wk of the flowering period and podding percentage of the flowers blooming each wk. Paclobutrazol (PB) was applied at the end of the flowering period. There was no significant difference in any of the values between the plants treated with PB and without treatment by t-test (P > 0.05).

Table 1. Flower number, percentage of podding, yield and yield component.

|                | Flower number | Podding percentage | Pod number | Pod yield | Seed number | Seed yield | Mean seed weight |
|----------------|---------------|--------------------|------------|-----------|-------------|------------|-----------------|
|                | (m²)          | (%) (m²)           | (g m⁻²)    | (m²)      | (g m⁻²)     | (g m⁻²)    | (g)             |
| Control        | 1288          | 15.7               | 197        | 310       | 288         | 197        | 0.59            |
| Treatment      | 1300          | 17.0               | 217        | 418       | 357         | 272        | 0.71            |
| Significance   | ns            | ns                 | ns         | **        | ns          | **          | **              |

*significant difference at the levels of 10% respectively. ns: not significant by t-test (P > 0.05). Flower number: total number of flowers blooming during a 5-wk flowering period. Podding percentage: average of the flowers blooming during a 5-wk flowering period.

PB treatment (Fig. 1). In the plants not treated with PB (control), the podding percentage of the flowers blooming within each wk increased with the delay of the blooming time until the 4th wk, then decreased drastically at the 5th wk. In the plants treated with PB, however, the podding percentage of the flowers blooming in the 1st to 4th wk was higher than 20% of the total, but that of the flowers blooming in the 5th wk was as low as that in the control. The podding percentage of the flowers blooming in the 1st to 3rd wk was higher in the plants treated with PB than in the control, though not significantly.

2. Yield and yield components
Table 1 shows yield and yield components. The number of pods and seeds and the percentage of podding were not significantly influenced but the pod yield, seed yield and mean seed weight were significantly increased by the treatment with PB. Fig. 2 indicates yield components from the flowers blooming each wk of the flowering period. The number of pods from the flowers blooming in the 1st wk was significantly increased by the treatment with PB, but that from the flowers blooming in the other wk was not. The pod yields from the flowers blooming in the 1st, 2nd and 3rd wk increased by PB resulting in a
significant increase in the total pod yield. The number of seeds produced from the flowers blooming in the 1st, 2nd and 3rd wk and that produced from the flowers blooming during the 5 wk in total, tended to be increased by PB. The seed yield from the flowers blooming in the 1st wk was also increased by PB. The mean weight of the seeds produced from the flowers blooming in the 1st and 4th wk and during the 5 wk in total (average of the
values for each wk) was significantly heavier in the plants treated with PB than in the control.

3. Photosynthetic rate and its related characteristics
PB significantly increased $\Phi_{\text{PSII}}$ in the plants at the 3rd wk after the treatment (Table 2). It also significantly increased CO$_2$ assimilation rate and the SPAD value indicating that the gain in chlorophyll content by the treatment with PB brought the increase in the efficiencies of both photosystem II and CO$_2$ assimilation. However, PB did not increase the SPAD value at the 4th wk after the treatment. Stomatal resistance and transpiration rate were not significantly influenced by PB.

PB did not significantly affect the crop growth rate (CGR), net assimilation rate (NAR) and mean leaf area index (LAI) during both the first and second two wk after the application (Table 3). However, it tended to increase CGR and NAR in the plants during the second two wk after the application.

**Discussion**

There are several reports on the effects of PB. But the results are not consistent. Some reports showed that PB increased chlorophyll content and CO$_2$ assimilation rates in strawberry (Ramina et al., 1985) and rape (Zhou and Xi, 1993), and that it increased chlorophyll content, but not CO$_2$ assimilation rate in rice (Yim et al., 1997). Others, however, showed photosynthesis-inhibitory effects of PB in strawberry (Archbold and Houtz, 1988) and grape (Hunter and Proctor, 1994). This inconsistency seems to be caused by the difference in the developmental stages (Senoo and Isoda, 2003) and/or cultivar of the plants used (Isoda et al., 1999). In the present experiment with peanut, the treatment with PB at the early pod formation stage increased chlorophyll content and $\Phi_{\text{PSII}}$, leading to higher CO$_2$ assimilation rates. In addition, CGR and NAR in the plants treated with PB were greater than those in the control during the second two wk after the treatment, although not significantly. However, PB did not effect the chlorophyll contents of the latest leaves at the 4th wk after the treatment. In addition, the CO$_2$ assimilation rate and chlorophyll content just after the treatment were also unaffected by PB (Senoo and Isoda, 2003). PB may therefore be efficacious on the characteristics related to photosynthesis only during a brief period at a restricted growing stage, suggesting that the gain in the photosynthetic efficiency might not be the main factor for increasing seed yield.

In the present experiment, treatment with PB increased the podding percentage. The podding percentage of the flowers blooming during the 1st and 2nd wk was particularly increased, leading to an increase in seed yield. Flowers that bloom early in the flowering stage tend to have higher podding percentages, and contribute to the seed yield (Fujiyoshi et al., 1956; Aoyama and Ebihara, 1964; Takeuchi et al., 1964). In soybean, Yoshida et al. (1983a,b) also reported that early blooming flowers had high percentages of podding. In our previous experiment, we applied PB to peanut plants at the three different stages of pod formation and found that the earliest treatment was the most effective for increasing seed yield (Senoo and Isoda, 2003). Michem et al. (1996) reported severe suppression of the growth of the main stem and cotyledonary lateral branches and increase in yield by the treatment with prohexadione calcium, a plant growth regulator. We also found the decrease in dry matter distribution to stems by the treatment with PB (Isoda et al., 1999; Senoo and Isoda, 2003). The major factor for increasing yield by PB might therefore be an acceleration of dry matter distribution to the early-bearing pods, which resulted from the inhibition of stem growth.

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