Short Communications

RETARDATION OF SHOOT GROWTH AND PROMOTION OF TUBER GROWTH OF POTATO PLANTS BY PACLOBUTRAZOL[1]

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Abstract

The relationship between shoot growth and tuber yield in potato plants (*Solanum tuberosum* L. cv. Russet Burbank) was studied under greenhouse conditions using paclobutrazol [(2R,3R + 2S,3S)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2-4-triazol-1-yl)-pentan-3-ol), PP333], a growth retardant. Concurrent with reduction of stem elongation by the application of paclobutrazol to base of the main stem was a decrease in the dry weight of the shoot and an increase in the dry weight of the tuber. The inhibitory effect of paclobutrazol on stem elongation was reversed by gibberellic acid A_3 (GA_3). Leaf content of raffinose sugar and chlorophyll increased upon paclobutrazol treatment.

Introduction

Total dry matter production and its distribution in different organs are important factors affecting tuber yield in potato plants (7, 8). When foliar growth is vigorous, considerable amounts of carbohydrates are utilized (5). Applications of growth retardants soon after tuber induction should cause a decrease in the shoot growth and an increase in the tuber growth by increasing the mobilization of assimilates and nutrients to the tuber (1, 4). Suppression of shoot growth has been achieved by the growth retardants such as CCC[3] (4) and B995[4] (3) which inhibit GA biosynthesis. Significant promotion of tuber yield resulted from the application of CCC (4, 9) and B995 (3). Paclobutrazol (PP333), an inhibitor of GA biosynthesis, has been shown to be very effective in inhibiting shoot growth in apples (6, 10) and sunflower (12). In our experiments, paclobutrazol treatment to potato plants resulted in the inhibition of shoot growth and a significant increase in the tuber growth.

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Abbreviations: [3]CCC-(2-chloroethyl)trimethylammonium chloride; [4]B995-chloroethylamino-succinamic acid.

KEY WORDS: Paclobutrazol, gibberellic acid, potato shoot growth, tuber yield, sugars.

Materials and Methods

Potato plants (*Solanum tuberosum* L. cv. Russet Burbank) were generated from 2 cm plugs taken from the eye area at the apical end of tubers. The plugs were sprouted in vermiculite in the dark until sprouts emerged and then the plants were grown under light. Single stem plants 5 cm in height were replanted in a soil mixture of 1 peat:1 perlite:1 soil held in 26 cm diameter plastic pots and grown in the greenhouse with 16 h light (24 C) and 8 h darkness (18 C). The soil mixture was irrigated twice a week with basic nutrient solution (100 ppm NPK and S.T.E.M. trace elements —S-1.5%, B-1.45%, Cu-3.2%, Fe-7.5%, Mn-8.15%, Mo-0.04%, Zn-4.5%). Tubers were observed to form one month after replanting. At this stage the height of the plants was about 53 cm. Plants of the same height were selected for further treatments. For the convenience of paclobutrazol treatments, all plants were maintained with single main stems by removing the branches growing close to the soil surface. Paclobutrazol (0.1% wt/wt) dissolved in 1% dimethylsulfoxide (v/wt) was mixed with lanolin and applied as a ring to the base of the stem one inch above the soil. GA_3 was applied as a foliar spray of 1 mM solution at weekly intervals.

For chlorophyll determination, 5 leaf discs (0.5 cm diameter) were removed with a cork borer and chlorophyll was extracted with 5 ml of 80% ethanol for 12 h at 55 C. The absorbance of chlorophyll was read at 665 nm. Soluble sugars were extracted with 80% ethanol and the neutral fraction obtained (11) was passed through SEP-PAK C_{18} cartridges (Waters Associates) to remove phenolic compounds. The soluble carbohydrates were analyzed by HPLC (Waters Associates) using Amino Bonded Phase column (250 × 6 mm Bio-Sil® Amino-5S, Bio-Rad). Acetonitrile (70%, v/v) filtered through a Millipore (FH-0.5 m) membrane was used as the mobile phase at a flow rate of 1 ml/min. Quantitation of each sugar was accomplished by fitting the peak area of the samples to the standard curve obtained by plotting the peak areas of different concentrations of standard sugars.

Results and Discussion

Various methods such as soil drench, foliar spray and painting on the stem or leaves have been tested for the application of paclobutrazol (2, 6, 10, 12). Paclobutrazol application to the stems of *Phaseolus vulgaris* and *Chrysanthemum morifolium* resulted in effective retardation of stem elongation (2). In our study, paclobutrazol (0.1%) mixed with lanolin was applied as a ring at the base of the stem one month after the plants were replanted. Plants were harvested 70 days after the treatments and fresh and dry weights of shoot, root, stolon and tubers were determined (Table 1). Paclobutrazol treatment resulted in a decrease in the shoot dry weight with a concomitant increase in the tuber dry weight. Tuber to shoot ratio in paclobutrazol-treated plants was 60% higher compared to control plants.

TABLE 1. — *Effect of paclobutrazol (PP333) on the growth of shoot, tuber, stolon and root of potato plants. Data are means (± SE) of values from 6 single plant replications in each treatment. Paclobutrazol treatment was given a month after the plants were replanted. Plants were harvested 70 days after treatment.*

Treatment	Fresh and Dry Weight per Plant (g)			Tuber/Shoot
	Shoot	Tuber	Stolon + Root	
Control				
F. Wt.	410.0 ± 28.4	328.8 ± 60.3	67.0 ± 5.1	0.8
D. Wt.	47.1 ± 5.3	61.8 ± 12.6	7.2 ± 0.3	1.3
+ Paclobutrazol				
F. Wt.	360.0 ± 25.5	505.5 ± 45.7	56.6 ± 9.3	1.4
D. Wt.	40.9 ± 0.8	85.0 ± 3.9	6.5 ± 0.5	2.1

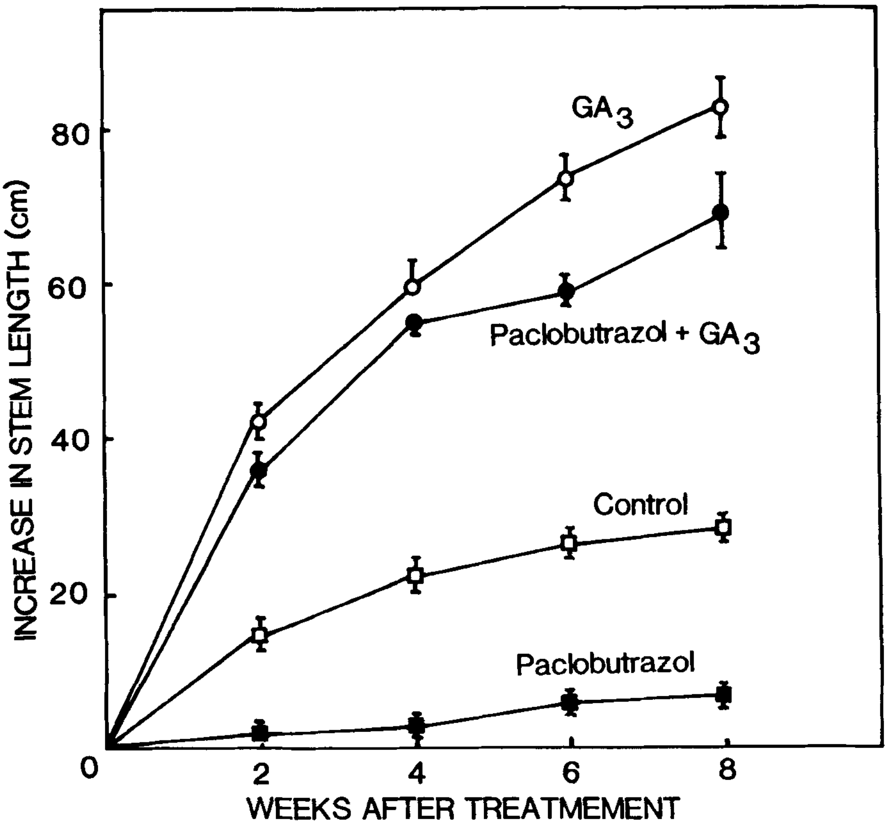

FIG. 1. Effects of paclobutrazol and GA_3 on the rates of potato stem growth. Treatments were started a month after replanting. Paclobutrazol (0.1%) mixed with lanolin was applied as a ring on the stem one inch above the soil. For GA_3 treatment, a solution of 1 mM GA_3 was sprayed on the leaves at weekly intervals. Values are means (± SE) of 7 single plant replications.

FIG. 2. Reversal of paclobutrazol-mediated inhibition by foliar spray of GA_3. The treatments were started a month after replanting. The duration of the treatments was 15 days.

These effects of paclobutrazol are comparable to the effects of other growth retardants such as CCC (4) and B995 (3).

Paclobutrazol inhibited stem elongation to 37% at 0.01% concentration, to 67% at 0.1% and to 76% at 1% concentrations (results not shown). Since the leaf margin turned necrotic at 1%, a concentration of 0.1% paclo-

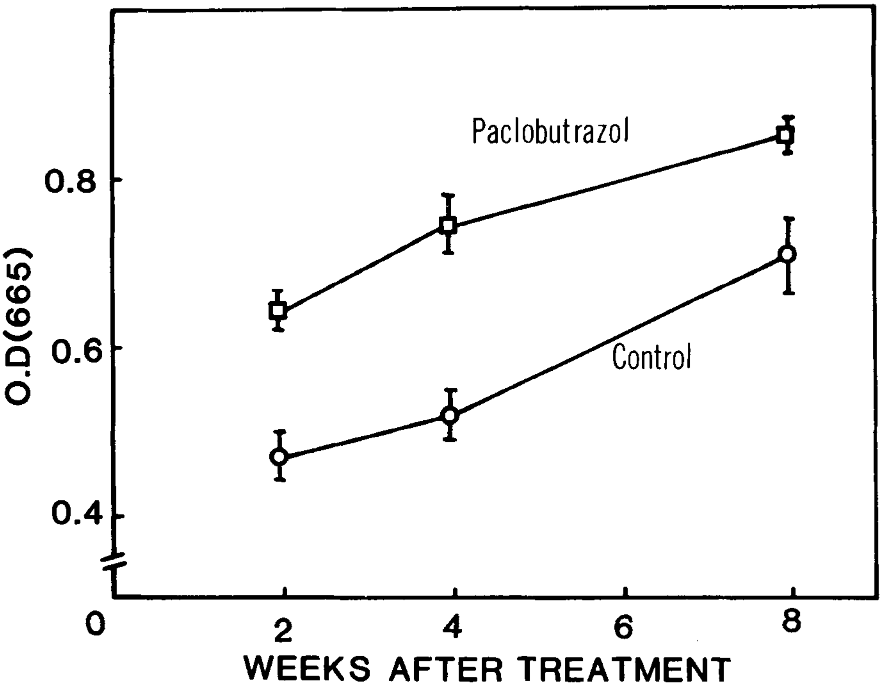

FIG. 3. Effect of paclobutrazol on chlorophyll content in leaves. Five leaf discs (0.5 mm) were excised from the fifth leaf from apex. Chlorophyll values are means (±SE) of determinations from 7 single plant replications.

butrazol was used in all experiments. The inhibitory effect of paclobutrazol on shoot growth was marked and was evident within two weeks after treatment (Figure 1). The internodal length of paclobutrazol-treated plants was 3.5-times shorter compared to that of control plants. When GA_3 was applied together with paclobutrazol, the inhibition of shoot growth was not observed and overall growth was comparable to the growth of GA_3-treated plants (Figure 2). The reversal of paclobutrazol-mediated growth inhibition by GA_3 in potato plants, as in other plants (6, 10, 12), indicated that paclobutrazol may inhibit shoot growth by causing a reduction in GA biosynthesis. Paclobutrazol-treated plants also appeared darker green in

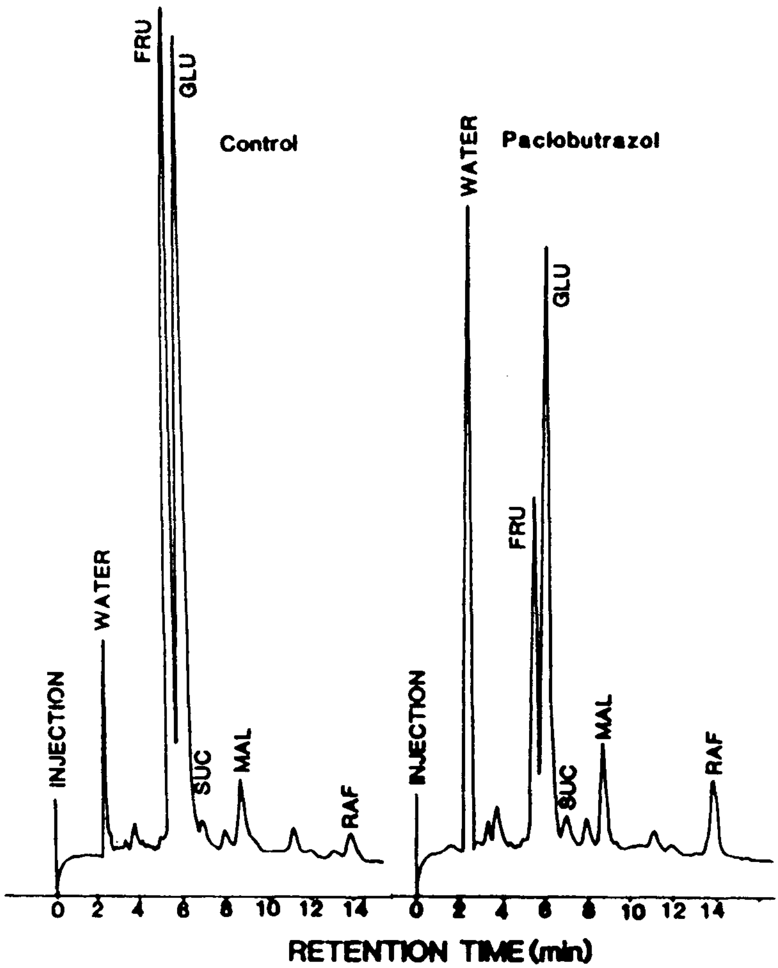

FIG. 4. HPLC analysis of soluble carbohydrates of leaves. Extracts corresponding to 50 mg fresh wt of control leaves and 100 mg fresh wt of paclobutrazol-treated leaves were used for analysis. Fru-fructose, Glu-glucose, Suc-sucrose, Mal-maltose, Raf-raffinose.

color compared to control plants. Chlorophyll content per unit area was consistently higher in the paclobutrazol-treated plants (Figure 3). The contribution of higher chlorophyll content to increased photosynthetic rates needs to be evaluated.

A 60% increase in the tuber to shoot ratio in paclobutrazol-treated plants as compared to the control plants suggested an effect of paclobutrazol on the partitioning of assimilates in favor of tuber growth. A study of soluble carbohydrates in leaves was made to evaluate the possible effects of paclobutrazol on carbon partitioning in leaves. Compared to the control plants, paclobutrazol-treated plants showed a decrease in the levels of most sugars. However, the content of raffinose was higher in paclobutrazol-treated plants (Figure 4). The fructose/glucose ratio which was 0.69 in the leaves of control plants decreased to 0.40 in the leaves of paclobutrazol-treated plants. The implications of these changes in sugars in the partitioning of carbohydrates in favor of tuber growth deserve further study.

Our results indicate that paclobutrazol is a powerful inhibitor of shoot growth at concentrations as low as 0.1%. In addition, paclobutrazol significantly altered the tuber to shoot ratio and also sugar metabolism and could therefore serve as a potentially useful compound to study the biochemical parameters which influence assimilate partitioning towards improving tuber yield.

Literature Cited

1. Arteca, R.N., B.W. Poovaiah and L.K. Hiller. 1980. Electron microprobe and neutron activation analysis for the determination of elemental distribution in hollow heart potato tubers. Am Potato J 57:241-247.
2. Barrett, J.E. and C.A. Bartuska. 1982. PP333 effects on stem elongation dependent on site of application. HortScience 17:737-738.
3. Bodlaender, K.B.A. and S. Algra. 1966. Influence of the growth retardant B 995 on growth and yield of potatoes. Eur Potato J 9:242-258.
4. Dyson, P.W. 1965. Effects of gibberellic acid and (2-chloroethyl)-trimethylammonium chloride on potato growth and development. J Sci Food Agric 16:542-549.
5. Gifford, R.M., J.H. Thorne, W.D. Hitz and R.T. Giaquinta. 1984. Crop productivity and photoassimilate partitioning. Science 225:801-808.
6. Greene, D.W. and J. Murray. 1983. Effect of paclobutrazol (PP333) and analogs on growth, fruit quality and storage potential of 'Delicious' apples. Proc Plant Growth Reg Soc Am 10:207-212.
7. Lovell, P.H. and A. Booth. 1967. Effects of gibberellic acid on growth, tuber formation and carbohydrate distribution in *Solanum tuberosum*. New Phytol 66:525-537.
8. Melis, R.J.M. and J. van Staden. 1984. Tuberization and hormones. Z Pflanzenphysiol 113:271-283.
9. Menzel, C.M. 1980. Tuberization in potato at high temperatures: Responses to gibberellin and growth inhibitors. Ann Bot 46:259-265.
10. Steffens, G.L., S.Y. Wang, C.L. Steffens and T. Brennan. 1983. Influence of paclobutrazol (PP333) on apple seedling growth and physiology. Proc Plant Growth Reg Soc Am 10:195-206.

11. Veluthambi, K., S. Mahadevan and R.Maheshwari. 1981. Trehalose toxicity in *Cuscuta reflexa:* correlation with low trehalase activity. Plant Physiol 68:1369-1374.

12. Wample, R.L. and E.B. Culver. 1983. The influence of paclobutrazol, a new growth regulator, on sunflowers. J Am Soc Hortic Sci 108:122-125.