International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(1): 387-391

Received: 08-11-2018
Accepted: 11-12-2018

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Influence of paclobutrazol on temperate fruit crops: A review

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Abstract
Paclobutrazol is a plant growth retardant and is antagonist of gibberellins. Paclobutrazol is used to alter growth, chlorophyll content, photosynthesis, transpiration, stomatal conductance and uptake of nutrient in different temperate fruit crops. It also improves plant resistance to drought stress, has darker green leaves, higher resistance against fungi and bacteria, and enhanced development of roots.

Keywords: Growth retardant, growth, water relations, nutrient uptake, fruits

Introduction
Paclobutrazol (PP333) (trade name: Cultar, Bonzi, Clipper, Parlay) is a plant growth retardant and belongs to triazole group of fungicides. It is an antagonist of gibberellin and hence is referred as 'antigibberellin'. Accordingly, many of paclobutrazol induced phenomenon in plants can be reversed by GA_3 (Davis, 1986) [17]. Chemical formula of paclobutrazol is $C_{15}H_20ClN_3O$ and chemical structure of paclobutrazol is [{2RS, 3RS} -1-(4 chlorophenyl)-4, 4- dimethyl -2-(1, 2, 4- triazol-1-yl)-pentan-3-ol]. Paclobutrazol causes reduction in cell division and overall vegetative growth which results a tree with more compact structure (Grochowska *et al.* 2004) [24]. It improves resistance to drought stress, has darker green leaves, higher resistance against fungi and bacteria, and enhanced development of roots. Among many plant growth retardants, paclobutrazol is commonly practiced by the horticultural growers. It can be applied through foliage or soil however, the application of paclobutrazol to soil as a drench around tree trunk (collar drench) is the most effective method. The required quantity is mixed with water and poured onto the soil around the trunk in a circular band. Therefore the use of paclobutrazol is increasing day by day in different fruit crops to influence different plant responses. Presently its use is also picking up in temperate fruit crops. Therefore the present review covers the influence of paclobutrazol on plant growth, water relations, physiology and leaf nutrient status in different temperate fruit crops.

Plant growth and vigour: Paclobutrazol prevents stem elongation (Hedden and Martin, 1985). PP333 decreased the elongation of new shoots in peach and the effect increased with increasing concentration from 500 to 1500 ppm (Zhang, 1990) [53]. Chen *et al.* (1995) [12] also noted that foliar sprays of PP333 at 1000 or 2000 mg a.i. per litre suppressed peach seedling growth. Shoot extension growth was reduced by 57 per cent at stone hardening and by 47.6 per cent at harvest following soil and collar drench of cultar (2.0 g a.i. PP333/tree) applied in autumn in peach cv. Flordaprince (George *et al.* 1995) [21]. Allan *et al.* (1993) [3] also observed significant reduction in competitive early vegetative growth by a soil drench of PP333 in peach cv. Flordaprince. Similarly, Biasi *et al.* (1989) [9] and George *et al.* (1993) [22] observed reduction in growth following PP333 treatment in peach and nectarine, respectively. Lever *et al.* (1982) [33] found more than 50 per cent reduction in shoot growth of Red Delicious apple following PP333 foliar spray at the rate of 750 ppm. However, the effectiveness of PP333 varied with the dose, time and method of application. Irving and Pallesen (1989) [29] found that on two year old apple 1000 ppm of PP333 had very little effect on vegetative growth and remained effective up to 82 days of application. But Stinchcombe *et al.* (1984) [45] reported that, in Cider apple, PP333 at 2000 ppm remained effective in the following year also. El-Khoreiby *et al.* (1990) [20] recorded maximum retardation in growth when PP333 was applied 21 days after petal fall. Similarly, Xia *et al.* (1994) [50] observed reduction in diameter, shoot and internode length in Fuji and Starking apple with the foliar sprays of 1000 ppm

Chengbhuabao (PP333). The reduction in shoot length of Fuji apples was also reported by Kim *et al.* (1990) [30]. Greene (1986) [23] observed the growth retardation effect of PP333 continuously for three years on apple trees when it was applied at higher rates of 1500-3000 ppm as foliar sprays. Mavrodiev and Manolov (1989) [35] reported that PP333 was less effective in controlling growth during the year of application but more effective during the following year. Quinlan and Richardson (1986) found that ^{14}C PP333 translocated acropetally when applied to young stem internodes and to a lesser degree, from the youngest unrolled leaf, however, there was no label moved from mature leaves. Paclobutrazol is also reported to regulate the vegetative growth of peach and cherry (Arzani *et al*. 2009; Brar, 2010) [7, 11]. Sharma and Joolka (2002a) [38] and Sharma and Joolka (2011) [41] recorded reduced extension growth, plant height and plant spread with paclobutrazol in Non Pareil almond plants. Mir *et al.* (2015) [36] reported that paclobutrazol significantly retarded the shoot growth, shoot diameter and trunk cross-sectional of 'Roundel' apricot trees growing under low density planting system.

Leaf area: Biasi *et al.* (1989) [9] applied 0.1 g PP333 per seedling as soil drench to Nemaguard peach and noted reduction in leaf area. Curry and Williams (1983) [15] found reduced leaf size of Well Spur Delicious apple with the application of 20 g PP333 per 9.5 m^2 as soil drench. Similar observations in apple have been made by Stinchcombe *et al.* (1984) [45], Swietlik and Miller (1985) [47], Chogtu (1986) Greene (1986) [23], Abod and Webster (1991) [1], Bhatia (1992) [8] and Xia *et al.* (1994) [50]. Val *et al*. (1999) [48] reported 40 per cent reduction in leaf area and 29 per cent reduction in dry weight of peach with paclobutrazol application.

Root growth: Soil drenching with 0.1 g of PP333 per plant resulted in reduced fresh and dry weight of root in containerized peach cv. Nemaguard seedlings (Biasi *et al.* 1989) [9]. Contrary to this, promotion in the root growth of apple trees with PP333 has been reported by Lenz (1984) [32], Steffens *et al.* (1984) [43] and Lehman *et al.* (1990) [31]. El-Hodairi *et al.* (1988) [19] found an increased root: shoot ratio and this was associated with a redistribution of ^{14}C-labelled assimilates in the plant. Dry matter accumulation in the roots, particularly in lateral and fibrous roots, increased with 1.5 g a.i. and 0.75 g a.i. PP333 applied in spring as soil drench in Aki Fuji apples (Huang *et al.* 1995) [27]. Similarly, Curry and Williams (1990) [16] recorded an increased root dry weight with the lower dose of PP333 but not with its higher dose. Whereas, Swietlik and Miller (1984) [46] reported that total root surface of apple seedling was not affected by PP333. Similarly, Abod and Webster (1991) [1] found no effect of 500 ppm PP333 spray on the root weight of MM106 apple rootstock. Bhatia (1992) [8] recorded reduced root length in MM109 apple rootstock treated with 1.0 g PP333 as soil drench. Similarly, Zeller *et al.* (1991a) [51] observed decrease in root growth of potted plants of Smoothee Golden Delicious apple when treated with 1, 10 or 100 mg PP333 per plant. Sharma and Joolka (2002a) [38] recorded reduced total root length and roots dry weight with paclobutrazol in Non Pareil almond plants.

Chlorophyll content: Leaf chlorophyll content in Fuji apple increased with foliar sprays of PP333 at 4 or 8 litres/ha (Kim *et al.* 1990) [30] and 1000 ppm (Xia *et al.* 1994) [50]. However, Steffens *et al.* (1993) [42] did not find any change in leaf chlorophyll content in own rooted, 4-year-old Gala apple trees in the third season after treatment with PP333. Sharma and Joolka (2003) [40] recorded increased leaf chlorophyll content with paclobutrazol in Non Pareil almond plants.

Photosynthesis, transpiration and stomatal conductance: Foliar sprays of PP333 increased photosynthetic activity in Fuji (Kim *et al.* 1990) [30] and Starking apples (Xia *et al.* 1994) [50]. In Leccino olive also, foliar spray of 1000 ppm PP333 lowered photosynthetic rate (Antognozzi *et al.* 1987) [6]. However, Antognozzi and Romani (1989) [5] did not found any effect of 2000 ppm PP333 on the photosynthetic activity of Golden Delicious apples. Similarly, Steffens *et al.* (1993) [42] did not record any effect of PP333 on the net photosynthesis of own rooted, 4-year-old Gala apples in the third season after the treatment. Leaf transpiration and CO_2 uptake were higher in Golden Delicious apple sprayed with 100 mg PP333 per tree in the first part of growing season and dropped to the level of control about 50 days following treatment (Bonomo *et al.* 1989) [10]. Stomatal conductance in Nemaguard peach seedlings reduced with the drenching of container soil with 0.1 g PP333 per plant (Biasi *et al.* 1989) [9]. While in strawberry, Deyton *et al.* (1991) recorded significantly higher leaf stomatal conductance with the foliar sprays of 75 to 1200 ppm PP333. However, Steffens *et al.* (1993) [42] did not find any effect of PP333 on the stomatal conductance of own rooted, 4-year-old Gala apple trees in the third season after treatment. Drenching the soil with 1.0 g PP333 per plant increased stomatal density in Vance Delicious and Red Spur Delicious apples (Bhatia, 1992) [8]. Sharma and Joolka (2002b) [39] recorded reduced the rate of photosynthesis and transpiration and stomatal conductance with paclobutrazol in Non Pareil almond plants.

Proline and abscisic acid contents: PP333 treatment increased the proline content in peach (Hu and Ding, 1993) [26]. Higher ABA content in the leaves of Vance Delicious and Red Spur Delicious apples was observed when plant soil was drenched with 1.0 g PP333 (Bhatia, 1992) [8]. Similarly, foliar sprays of 1000 ppm Chenghuabao (PP333) combined with girdling resulted in maximum ABA content in Fuji and Starking apple leaves (Xia *et al.* 1994) [50]. Sharma and Joolka (2003) [40] recorded more leaf proline and abscisic acid content with paclobutrazol in Non Pareil almond plants.

Carbohydrate content: PP333 influences the carbohydrate contents in plants. Pith and xylem starch deposits in Sudanell-1 peach increased with PP333 (Aguirre and Blanco, 1992) [2]. Vance Delicious and Red Spur Delicious apples had more leaf total sugar with 0.5 g PP333 and leaf starch with 1.0 g PP333 per plant applied as soil drench (Bhatia, 1992) [8]. However, Xia *et al.* (1994) [50] recorded increased leaf sugar and starch contents in Fuji and Starking apples on treatment with 1000 ppm Chenghuabao (PP333). In Spartan apples treated with PP333, Steffens *et al.* (1985) [44] found higher leaf starch and static sugar contents. Whereas in Top Red Delicious plants treated with PP333, Wieland and Wample (1985) [49] observed reduction in reducing sugars with 150 mg, increase in starch with 25 and 50 mg than those with 150 mg dose of PP333. In apple plants PP333 treatments resulted in the depletion of carbohydrates (Curry, 1988) [14] and starch in shoots (Bonomo *et al.* 1989) [10]. Zeller *et al.* (1991b) [52] observed the effect of PP333 in altering the levels of carbohydrates in apple plants grafted on M7A but not in plants on MM111 rootstock. On

the other hand, Antognozzi and Romani (1989) [5] could not find any effect of 2000 ppm PP333 on the sugar and starch contents of Golden Delicious apple leaves. However, Sharma and Joolka (2003) [40] observed increased leaf total carbohydrates content with paclobutrazol in Non Pareil almond plants.

Nutrient uptake

PP333 influence the leaf nutrient status of various temperate fruit crops.

Nitrogen: PP333 treatment reduced foliar N concentration in Nemaguard (Rieger, 1990) [37], Flordaprince (Allan *et al.* 1993, 1995) [3], Flordaprince and Flordagold peach cultivars (Huett *et al.* 1997) [28] and Red Spur Delicious and Vance Delicious apples (Bhatia, 1992) [8]. However, Atikson and Crisp (1983) found increased foliar N concentration in apple plants treated with PP333. But Swietlik and Miller (1985) [47] could not find any effect of PP333 on the foliar N levels of Golden Delicious apples. However, Sharma and Joolka (2011) [41] recorded reduced leaf N content with paclobutrazol in Non Pareil almond plants.

Phosphorus: PP333 treatment reduced foliar P concentration in Nemaguard, (Rieger, 1990) [37], Flordaprince (Allan *et al.* 1993, 1995) [3], Flordaprince and Flordagold peach cultivars (Huett *et al.* 1997) [28] and Red Spur Delicious and Vance Delicious apples (Bhatia, 1992) [8]. Increased foliar P concentration in apple plants treated with PP333 has been reported by Atikson and Crisp (1983) and Curry (1988) [14]. However, Sharma and Joolka (2011) [41] recorded reduced leaf P content with paclobutrazol in Non Pareil almond plants.

Potassium: PP333 treatment reduced foliar K contents in Nemaguard (Rieger, 1990) [37], Flordaprince peach (Allan *et al.* 1993, 1995) [3], stone fruits (Lichou *et al.* 1988) [34], Red Spur Delicious, Vance Delicious (Bhatia, 1992) [8] and Ace Delicious apple (Curry, 1988) [14]. Contrary to this, Swietlik and Miller (1984) [46] observed increase in K uptake with the addition of 0.2 ppm PP333 to a nutrient solution in which 11 month old apple seedlings were grown. However, Sharma and Joolka (2011) [41] recorded reduced leaf K content with paclobutrazol in Non Pareil almond plants.

Calcium: Increased concentration of foliar Ca with PP333 treatment was observed in Nemaguard (Rieger, 1990) [37], Flordaprince (Allan *et al.* 1993, 1995) [3], Flordaprince and Flordagold peach cultivars (Huett *et al.* 1997) [28] and Red Spur Delicious and Vance Delicious apples (Bhatia, 1992) [8]. Similar observations regarding the increase in foliar Ca concentrations in various apple cultivars were made by Atikson and Crisp (1983), Swietlik and Miller (1984) [46], Curry (1988) [14] and Bonomo *et al.* (1989) [10]. Swietlik and Miller (1985) [47] further reported that Ca content in Golden Delicious increased in proportion to the increasing doses of PP333. Sharma and Joolka (2011) [41] also recorded increased leaf Ca content with paclobutrazol in Non Pareil almond plants.

Magnesium: Foliar Mg content has been reported to increase with PP333 treatment in Nemaguard (Rieger, 1990) [37], Flordaprince (Allan *et al.* 1993, 1995) [3], Flordaprince and Flordagold peach cultivars (Huett *et al.* 1997) [28], Red Spur Delicious and Vance Delicious apples (Bhatia, 1992) [8] and apple plants (Bonomo *et al.* 1989) [10]. But Curry (1988) [14] found reduced levels of foliar Mg in apple plants treated with PP333. However, Sharma and Joolka (2011) [41] also recorded increased leaf Mg content with paclobutrazol in Non Pareil almond plants.

References

1. Abod SA, Webster AD. The influence of foliar sprays of tetcyclasis or paclobutrazol on the growth and water use of transplanted Malus, Tilia and Bitula stocks. J Hort. Sci. 1991; 66:85-94.
2. Aguirre R, Blanco A. Patterns of histological differentiation induced by paclobutrazol and G~ in peach shoots. Acta Hortic. 1992; 315:7-12.
3. Allan P, George AP, Nissen RJ, Rasmussen TS, Morley Bunker MJ. Effects of paclobutrazol on phenological cycling of low chill 'Flordaprince' peach in subtropical Australia. Scientia Hortic. 1993; 53(1-2):73-84.
4. Allan P, George AP, Nissen RJ, Rasmussen TS, Shaltout AD. Phenology and management practices of 'Flordaprince' peach. Acta Hortic. 1995; 409:19-24.
5. Antognozzi E, Romani F. Effects of paclobutrazol (PP333) and of pruning on the vegetative and productive activities of cv. Golden Delicious apple trees. Annali della facolta di Agraria, Univ. degli studi di Perugia. 1989; 41:281-293.
6. Antognozzi E, Preziosi P, Standardi A. Effects of paclobutrazol (PP333) on the vegetative activity and the course of photosynthesis in olive trees in the nursery. Annali della facolta di Agraria, Univ. degli Studi di Perugia. 1987; 41:827-838.
7. Arzani K, Bahaderi K, Piri S. Paclobutrazol reduces vegetative growth and enhances flowering and fruiting of mature ‘J.H. Hale’ and ‘Red Skin’ peach trees. Horticulture, Environment and Biotechnology. 2009; 50:84-93.
8. Bhatia SK. Effect of paclobutrazol, daminozide and rootstocks on the growth and chemical composition of apple plant. Ph.D. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, India, 1992.
9. Biasi R, Costa G, Succi F. Paclobutrazol and root zone water content influence peach seedling behaviour. J Amer. Soc. Hort. Sci. 1989; 114(6):923-926.
10. Bonomo R, Neri D, Sansavini S. Dry matter and nutrient partioning, seasonal water consumption and gas exchange of paclobutrazol growth-controlled apple trees. Acta Hortic. 1989; 239:159-166.
11. Brar JS. Influence of paclobutrazol and ethephon on vegetative growth of guava (*Psidium guajava* L.) plants at different spacing. Notulae Scientia Biologicae. 2010; 2(3):110-113.
12. Chen D, Shen D, Zailong L. Effects of PP333 on early flowering of peach seedlings. Acta Agric. 1995; 7(1):20-23.
13. Chogtu SK. Effect of spacing and paclobutrazol (PP333) on photosynthetic efficiency, growth and yield of Royal Delicious apples. M.Sc. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, India, 1986.
14. Curry EA. Chemical control of vegetative growth of deciduous fruit trees with paclobutrazol and RSWO 411. Hort. Sci. 1988; 23:470-473
15. Curry EA, Williams MW. Promalin or GA_3 increase pedicel and fruit length and leaf size of Delicious apples treated with paclobutrazol. Hort. Sci. 1983; 18:214-215.

16. Curry EA, Williams MW. Influence of rootstock on response of Delicious and Golden Delicious trees treated with paclobutrazol. Fruit Var. J. 1990; 44(3):172-176.
17. Davis TD. Influence of triazole growth retardants on adventitious root formation in bean hypocotyl cutting. Proc. Plant Growth Reg. Soc. Am. 1986; 13:217-223.
18. Deyton DE, Sams CE, Cummins JC. Strawberry growth and photosynthetic responses to paclobutrazol. Hort. Sci. 1991; 26(9):1178-1180.
19. EI-Hodairi MH, Canham AE, Buckley WR. The effects of paclobutrazol on growth and the movement of ^{14}C-labelled assimilates in Red Delicious apple seedlings. J Hort. Sci. 1988; 63:575-581.
20. El-Khoreiby AM, Unrath CR, Lehman LJ. Paclobutrazol spray timing influences apple tree growth. Hort. Sci. 1990; 25:310-312.
21. George AP, Nissen RJ, Rassmussen T. Effects of postharvest topping, autumn cincturing, and paclobutrazol on growth, yield and fruit quality of the low chill nectarine cv. Sundowner in subtropical Australia. Aust. J Expt. Agric. 1993; 33(3):353-362.
22. George AP, Nissen RJ, Campbell JA, Rasmussen T, Allan P, Shaltow AD. Effects of paclobutrazol on growth and yield of low chill peaches in subtropical Australia. Acta Hortic. 1995; 409:109-116.
23. Greene DW. Effect of paclobutrazol and analogs on growth, yield, fruit quality and storage potential of Delicious apples. J Amer. Soc. Hort. Sci. 1986; 111:328-332.
24. Grochowska MJ, Hodum M, Mika A. Improving productivity of four fruit species by growth regulators applied once in ultra-low doses to the collar. Journal of Horticultural Science & Biotechnology. 2004; 79:252-259.
25. Hedden P, Martin GC. Inhibition of gibberellin biosynthesis by paclobutrazol in cell free homogenates of Cucurbita maxima endosperm and Malus pumila embryos. J Pl. Growth Reg. 1985; 4:111-122.
26. Hu XS, Ding SY. Effects of paclobutrazol on post-harvest physiology and patterns of respiration and ethylene production of peach fruits. Acta Agric. 1993; 19(1):53-60.
27. Huang WO, Shen T, Han ZH, Liu S. Influence of paclobutrazol on photosynthesis rate and dry matter partitioning in the apple tree. J Pl. Nutr. 1995; 18(5):901-910.
28. Huett DO, George AP, Slack JM, Morris SC. Diagnostic leaf nutrient standards for low-chill peaches in subtropical Australia. Aust. J Exp. Agric. 1997; 37(1):119-126.
29. Irving DE, Pallesen JC. Growth retarding effects of paclobutrazol and RSWO 411 on Granny Smith and Fuji apple trees. J PI. Growth Reg. 1989; 8:199-204.
30. Kim JK, Kim KY, Kim JB, Kim SB. The effect of paclobutrazol on shoot growth, photosynthetic activity, leaf and fruit characteristics and flower bud formation in Fuji apples. Res. Reports Rural Dev. Admins. Hort. 1990; 32(2):10-15.
31. Lehman LJ, Young E, Unrath CR. Apple tree vigour influences flowering and dry weight after paclobutrazol application. Hort Sci. 1990; 25:933-935.
32. Lenz F. PP333- an interesting growth retardant. Erweb. 1984; 26:244.
33. Lever BG, Shearing SJ, Batch JJ. PP333- A new broad spectrum growth retardant. Proc. British Crop Protec. Conf. Weeds, 1982, 3-10.
34. Lichou J, Devlavnay V, Garcin A, Vidaud J, Jay M. Application of paclobutrazol to stone fruit trees. Effects on vegetative growth and fruiting. CTIFL-INRA, 1988, 215-217.
35. Mavrodiev SG, Manolov PB. A practical approach to use paclobutrazol (Cultar) on apples in Bulgaria. Acta Hortic. 1989; 239:273-276.
36. Mir MM, Baba JA, Umar I, Rather GH, Rehman MU, Banday SA *et al*. Effect of soil applied paclobutrazol on vegetative growth and quality attributes of apricot (*Prunus armeniaca* L.). Green Farming Int. J. 2015; 6(4):813-813.
37. Rieger M. Paclobutrazol, root growth, hydraulic conductivity and nutrient uptake of 'Nemaguard' peach. Hort. Sci. 1990; 25(1):95-98.
38. Sharma MK, Joolka NK. Growth and water relations of Nonpareil almond as influenced by growth regulators. The Hort. Journal, 2002a; 15(2):83-86.
39. Sharma MK, Joolka NK. Effect of bioregulators and rootstocks on growth, photosynthetic efficiency and water relations of Nonpareil almond. Annals of Agricultural Research, 2002b; 23(4):740-743.
40. Sharma MK, Joolka NK. Bioregulators mediated biochemical changes in Nonpareil almond under soil water stress. Haryana J Hort. Sci. 2003; 32(3&4):182-184.
41. Sharma MK, Joolka NK. Influence of triacontanol and paclobutrazol on growth and leaf nutrient status of Non Pareil almond under different soil moisture regimes. Indian Journal of Horticulture. 2011; 68(2):180-183.
42. Steffens GL, Jacobs FW, Engelhaupt ME. Size, flowering and fruiting of maturing own-rooted 'Gala' apple trees treated with paclobutrazol sprays and trunk drenches. Scientia Hortic. 1993; 56(1):13-21.
43. Steffens GL, Wang SY, Byun JK. Effects of altering gibberellin availability on growth and chemical composition of apple seedlings. Proc. 11th Annual Meeting, PI. Growth Reg. Soc. America, 1984, 45.
44. Steffens GL, Wang SY, Faust M, Byun JK. Growth, carbohydrate and mineral element status of shoot and spur leaves and fruit of Spartan apple trees treated with paclobutrazol. J Amer. Soc. Hort. Sci. 1985; 110:850-855.
45. Stinchcombe GR, Copas E, Williams RR, Arnold G. The effects of paclobutrazol and daminozide on the growth and yield of cider apple trees. J Hort. Sci. 1984; 59:323-327.
46. Swietlik D, Miller SS. The effect of paclobutrazol on the growth and uptake of Ca and K by apple seedlings. J Plant Nutr. 1984; 7:1555-1556.
47. Swietlik D, Miller SS. The effect of paclobutrazol on mineral nutrition of apple seedlings. J Plant Nutr. 1985; 8:369-382.
48. Val J, Pequerul A, Mange E, Blanco A. Reduced nutrient uptake in peach trees treated with paclobutrazol. Acta Horticulturae. 1999; 465:163-168.
49. Wieland WF, Wample RL. Effects of paclobutrazol on growth, photosynthesis and carbohydrate content of Delicious apples. Scientia Hortic. 1985; 26:139-147.
50. Xia C, Zhou P, Shen M, Xia CS, Zhou P, Shen MP. Physiological effects of Chenghuabao and girdling on apple trees. Jiangsu J Agric. Sci. 1994; 10(3):57-61.

51. Zeller JK, Larson FE, Higgins SS, Curry EA. Rootstock effects on responses of potted 'Smoothee Golden Delicious' apple to soil-applied triazole growth inhibitors I. Shoot and root growth. Scientia Hortic. 1991a; 46:61-74.
52. Zeller JK, Larson FE, Higgins SS, Raese JT, Fellman JK. Rootstock effects on responses of potted 'Smoothee Golden Delicious' apple to soil-applied triazole growth inhibitors. II. Mineral nutrition and carbohydrate status. Scientia Hortic. 1991b; 46:75-88.
53. Zhang ZH. The effects of paclobutrazol on peach trees at the early fruiting stage. Jiangsu Nongye Kexue. 1990; 1:49-50.