The Effects of B*enzyladenine* Applications on Branching of 'Mondial Gala' Apple Nursery Trees on MM.106 in the First Year Growth

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ABSTRACT: Mondial Gala apples grafted on MM.106 rootstocks develop vigorous nursery trees with only a few poorly distributed long laterals, which is undesirable for early fruiting. Nursery trees of Mondial Gala / MM.106 were sprayed with 0, 200 or 400 mg l^{-1} of 6-benzyladenine (BA) in order to improve lateral shoot formation. BA spraying began in mid-June when the growing scion shoots were 60–65 cm above the bud union, and actively growing scion shoots with leaves were sprayed 1, 2, 3, 4 or 5 times at 3-day interval. The BA treatments significantly increased the total number and total length of laterals per tree compared with the untreated trees. The average length and diameters of laterals were also affected by the BA treatments. BA treated trees had significantly wider crotch angles. Two or three sprays of 200 mg l^{-1} BA seemed sufficient to form at least four vigorous laterals (30–50 cm) and two medium growth laterals (10–30 cm) with wider crotch angles.
Keywords: Mondial Gala, MM.106, branching, 6-benzyladenine, apple.

Benziladenin Uygulamalarının MM.106 Üzerine Aşılı Mondial Gala Elma Fidanlarının İlk Gelişme Yılındaki Dallanması Üzerine Etkileri

ÖZET: Mondial Gala elma çeşidinin MM.106 anacına aşılı fidanları kuvvetli gelişen ve iyi dağılım göstermeyen bir iki adet yan dal oluşturmaktadır. Bu özellik, fidanların erken yaşta meyveye yatmasını güçleştirmektedir. Bu araştırmada MM.106 üzerine aşılanan Mondial Gala elma fidanlarının yan dal oluşumunu iyileştirmek amacıyla fidanlıktaki aşılı bitkilere 0, 200 ve 400 mg/l 6-benziladenin (BA) püskürtülmüştür. BA uygulaması haziran ayının ortasında aşı sürgünleri aşı yerinden 60-65 cm kadar uzadığı dönemden başlayarak aktif büyüyen sürgünlere ve yapraklara püskürtme şeklinde 3'er gün aralıklarla 1,2,3,4 ya da 5 kez yapılmıştır. BA uygulanan fidanların toplam yan dal sayısı ve toplam yan dal uzunluğu tanık uygulamasına göre önemli ölçüde artmıştır. BA uygulamaları yapılan fidanlardaki yan dalların ortalama uzunluğu ve kalınlığı da daha fazla olmuştur. Ayrıca, BA uygulanan fidanlarda yan dalların gövde ile yaptığı açıların daha geniş olduğu belirlenmiştir. Fidanlara iki ya da üç kez 200 mg/l BA püskürtülmesiyle, geniş açıyla büyüyen, 30-50 cm uzunluğunda en az dört adet kuvvetli yan dal ile 2 adet orta kuvvette yan dal elde edilebileceği anlaşılmıştır.
Anahtar kelimeler: Mondial Gala, MM.106. dallanma, 6-benziladenin, elma.

INTRODUCTION

Lateral branch development has been reported to be beneficial for increasing the bearing surface and in promoting early production in apple plantings (Quinlan and Preston, 1978; Van Oosten, 1978; Ferree and Rhodus, 1987; Quinlan and Tobutt, 1990). Accordingly, many nurseries routinely produce branched (feathered) trees for dwarf apples. Despite this, semi-dwarf apple nursery trees (mainly on MM.106 rootstocks) are still being grown as whips or poorly branched trees. The usual practice in developing scaffold branches on central-leader trees in semi-dwarf apples includes dormant heading at planting with the removal of a few long feathers. However, it has been reported (Ferree, 1981) that dormant heading of one-year-old wood often stimulates the uppermost few buds to develop into vigorous laterals. This, in turn, decreases the potential fruiting area (Elfving and Forshey, 1976) and also delays fruiting (Ouellette et al., 1996).

Contrary to the trend to intensively planted apples on M.9 rootstocks, many Turkish growers are continuing to establish semi-intensive apple plantings with newer cultivars budded onto MM.106 rootstocks. Also, in some Asian countries, interest in MM.106 rootstocks has continued (Tareen et al., 2002). In these countries, the main reasons for preferring semi-intensive plantings with MM.106 rootstocks are the low establishment costs and easy management practices. A detailed economical analysis showed that semi-intensive apple plantings on MM.106 rootstocks could be commercially profitable over a projected orchard lifetime of 25 years (Jackson et al., 1986), and semi-intensive apple growing was recommended as a profitable method of management for commercial use (McKenzie and Rae, 1978).

MM.106 rootstocks make productive trees on relatively poor soils because of their vigorous growth (Tukey, 1983). Gala apples are also quite vigorous (Walsh and Thompson, 1990). This includes the Mondial Gala scion, which is increasing in popularity. Thus, the resulting combination of Mondial Gala and MM.106 constitutes rather vigorous nursery trees with only a few poorly distributed long feathers, which is undesirable for early production. Therefore, improvement in the branching of this scion-rootstock combination is needed.

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Various chemicals have been used to obtain well-branched trees at the nursery level or to improve branching in young trees (Baldini et al., 1973; Cody et al., 1985; Greene and Autio, 1990; Quinlan and Tobutt, 1990). Although it is well known that BA alone or a combination of BA and gibberelic acid (GA) increase the sylleptic branching of apple shoots, the application method and concentration of the chemicals are thought to be important for obtaining the desired physiological effect in various fruit trees (Childers et al., 1995). Hrotko et al. (1996) reported a positive effect of repeated BA treatments on stimulating branching in one-year-old Idared / M.26 nursery trees.

The objective of this study was to investigate the effect of two concentrations of 6-benzyladenine with repeated treatments on the branching of Mondial Gala / MM.106 apple nursery trees.

MATERIAL and METHOD

The experiment was carried out at a commercial apple nursery, near Kahramanmaraş Province, Turkey, that was established on a loamy soil with 1.5% organic material content. The location of the nursery was 37°56' north latitude and 36°56' east longitude, with an altitude of 640 m. The annual precipitation on average over 10 years was 600 mm, and the average monthly temperatures during BA sprayings were 25.5 °C in June and 29.1 °C in July. No rainfall occurred during the summer and autumn months.

Plant material. Well-developed MM.106 rootstocks (10–12 mm diameter) were T-budded with 'Mondial Gala' apple scions in September 2002. They were then dormant-headed to induce scion shoot growth in mid-March 2003 at just above the budding point, which was 15 cm above the soil line. The nursery trees were 30 cm within each row and 90 cm apart between rows. Plots were furrow-irrigated and trees received standard nursery practices. The nursery trees were homogenous in growth because of the careful nursery practices used. After the occurrence of lateral shoots, trees received adequate foliar fertilization (containing macros 20-20-20 and Fe) three times at 20-day interval to support new growth. The apple trees dropped their leaves in mid-December.

BA treatments. The BA concentrations used were 0, 200 and 400 mg l^{-1}, and they were first applied on 15 June 2003, when the growing scion shoots were 60–65 cm above the bud union. Applications were continued with repeated sprayings at 3-day interval for up to five occasions (Table 1). BA was applied to the nursery trees in distilled water with the addition of Tween 20 as a non-ionic surfactant (Hrotko et al., 1996). The upper 20 cm of actively growing scion shoots with leaves were sprayed with atomizer-type hand sprayers (Cody et al., 1985), and each tree received 25 ml solution. The untreated (control) trees were sprayed with only water at each spraying. In the experiment, each plot consisted of 15 plants with three replications (45 trees in each combination) in randomized blocks.

Data collection. At the end of the growing season, the current season's lateral shoots were divided into four groups: 30–50 cm, 10–30 cm, 5–10 cm, and < 5 cm. The following measurements were taken: number, length and diameter of laterals, lateral angles from the vertical using a protractor, tree heights from the budding point, and stem diameters at 20 cm above the bud union. Data were statistically analyzed, and treatment means were separated using the least significant difference test ($P \leq 0.05$). Means and SDs are presented in the tables.

RESULTS

BA treatments significantly increased the total number of lateral shoots per tree compared with the untreated trees (control) when measured after leaf fall (Table 1). While the total number of lateral shoots per tree was 2.8 in the control, it changed between 8.0 and 9.3 with the BA 200 × 1–2 sprays, and between 6.3 and 7.1 with the BA 400 × 3–5 sprays, which were statistically in the same group. Although the number of laterals with the BA 400 × 1–2 sprays was statistically lower (4.2 and 4.7) than that of all other BA sprays, it was still significantly higher than the control. Despite not being statistically significant, repeated BA sprays tended to form more laterals per tree than did single BA sprays at both concentrations. Apparently, the BA treatments induced more buds to burst and develop into lateral shoots compared with the control trees. The BA treatments also influenced the number of laterals per length class. In all BA treated trees, the number of laterals 30–50 cm in length were significantly greater than that of the control. In this length class, the mean number of laterals per tree with BA sprays ranged from 3.4 to 5.2 compared with the control trees (1.8). Similarly, the mean number of laterals in the 10–30 cm length class was significantly increased by the BA treatments (between 1.8 and 2.7) compared with the control (0.9). An exception was with BA 400 × 1–2 sprays. The number of 5–10 cm laterals with the BA 200 sprays was also greater than with the BA 400 sprays or the control trees. The number of laterals < 5 cm with the BA 200 × 1–4 sprays was statistically different from the BA 200 × 5 and the BA 400 × 1 sprays, and no laterals were formed in this class with repeated BA 400 sprays. The latter two results may indicate that the lower concentration of BA (200 mg l^{-1}) was more effective in increasing overall lateral shoot formation than the higher concentration of BA (400 mg l^{-1}) in Mondial Gala / MM.106 nursery trees.

Table 1. Effect of BA treatments on lateral shoot formation of Mondial Gala / MM.106 nursery trees.[z]

BA concentrations (mg l^{-1}) and applications[y]	Total lateral shoot number / tree	Number of laterals per length class / tree			
		30<-50 cm	10<-30 cm	5-10 cm	< 5 cm
Untreated control	2.8 ± 0.5 c[x]	1.8 ± 0.4 b	0.9 ± 0.2 b	0.1 ± 0.1 b	-
BA 200 x 1 spray	8.0 ± 2.1 a	3.4 ± 1.5 a	1.8 ± 0.1 a	2.0 ± 0.2 a	0.8 ± 0.2 a
BA 200 x 2 sprays	9.3 ± 3.4 a	4.6 ± 1.0 a	2.7 ± 0.2 a	1.4 ± 0.1 a	0.6 ± 0.3 a
BA 200 x 3 sprays	9.0 ± 2.5 a	4.5 ± 1.2 a	2.5 ± 0.2 a	1.3 ± 0.1 a	0.7 ± 0.1 a
BA 200 x 4 sprays	9.2 ± 2.6 a	4.5 ± 0.9 a	2.0 ± 0.1 a	1.9 ± 0.3 a	0.8 ± 0.1 a
BA 200 x 5 sprays	8.4 ± 2.0 a	4.9 ± 1.0 a	2.5 ± 0.5 a	0.9 ± 0.1 a	0.1 ± 0.1 b
BA 400 x 1 spray	4.2 ± 1.0 b	3.6 ± 0.5 a	0.4 ± 0.1 b	0.1 ± 0.1 b	0.1 ± 0.2 b
BA 400 x 2 sprays	4.7 ± 1.0 b	3.6 ± 0.7 a	1.1 ± 0.4 ab	-	-
BA 400 x 3 sprays	6.3 ± 1.6 a	4.2 ± 0.7 a	1.8 ± 0.2 a	0.3 ± 0.1 b	-
BA 400 x 4 sprays	7.1 ± 1.8 a	4.5 ± 0.5 a	1.9 ± 0.2 a	0.6 ± 0.2 b	-
BA 400 x 5 sprays	7.0 ± 1.9 a	5.2 ± 1.0 a	1.8 ± 0.3 a	-	-

[z] Data shown are means of 45 plants (15 plants with 3 replications).
[y] Repeated sprays were applied at 3-day interval, starting from 15 June 2003.
[x] Mean separation within columns by least significant differences at $P \leq 0.05$.

The total length of laterals per tree was greatly increased with the BA treatments in Mondial Gala / MM.106 nursery trees (Table 2). The control had a total lateral length of 114.8 cm but, for the BA treated trees, this value was often about two or three times greater and ranged from 220 to 409 cm (except for the BA 400 × 1 spray). Although not statistically significant, the total length of laterals per tree tended to increase with repeated BA sprays compared with the single BA spray at both BA concentrations. The increased number of laterals formed by BA treatments could have been responsible for the increase in the total length of laterals.

The average length of laterals per tree was also affected by the BA treatments (Table 2). It was 41.0 cm in the control, whereas it was reduced by the BA 200 × 1, 2 and 3 sprays to 27.9, 31.0 and 33.5 cm, respectively. Nevertheless, these lengths can be sufficient for well-feathered trees. The average length of the laterals obtained with all other BA treatments did not differ statistically from the control.

Table 2. Effect of BA treatments on the total and average length, diameter and angle of crotches of the laterals on Mondial Gala / MM.106 nursery trees.[z]

BA concentrations (mg l^{-1}) and applications[y]	Total length of laterals / tree (cm)	Average length of laterals/ tree (cm)	Diameter of laterals (cm)	Angle of lateral crotches (^{o})
Untreated control	114.8 ± 26 b[x]	41.0 ± 2.5 a	0.6 ± 0.1 b	45 ± 16 a
BA 200 x 1 spray	223.2 ± 18 a	27.9 ± 4.4 b	1.0 ± 0.1 a	70 ± 12 b
BA 200 x 2 sprays	288.3 ± 10 a	31.0 ± 4.6 b	1.2 ± 0.1 a	80 ± 10 b
BA 200 x 3 sprays	301.5 ± 13 a	33.5 ± 4.6 b	1.2 ± 0.1 a	85 ± 20 b
BA 200 x 4 sprays	409.4 ± 17 a	44.5 ± 4.7 a	0.9 ± 0.2 a	78 ± 12 b
BA 200 x 5 sprays	367.2 ± 13 a	43.8 ± 4.2 a	0.9 ± 0.1 a	85 ± 15 b
BA 400 x 1 spray	176.4 ± 19 b	42.0 ± 5.6 a	1.3 ± 0.2 a	80 ± 12 b
BA 400 x 2 sprays	220.4 ± 12 a	46.9 ± 4.9 a	1.5 ± 0.2 a	75 ± 8 b
BA 400 x 3 sprays	253.8 ± 15 a	40.3 ± 3.4 a	0.6 ± 0.1 b	85 ± 10 b
BA 400 x 4 sprays	290.3 ± 21 a	40.9 ± 3.1 a	0.6 ± 0.1 b	80 ± 8 b
BA 400 x 5 sprays	301.0 ± 20 a	43.0 ± 3.2 a	0.5 ± 0.2 b	80 ± 8 b

[z] Data shown are means of 45 plants (15 plants with 3 replications). Angle of lateral crotchs are means of four well-developed branches of 15 plants.
[y] Repeated sprays were applied at 3-day interval, starting from 15 June 2003.
[x] Mean separation within columns by least significant differences at $P \leq 0.05$.

In general, the BA treatments increased the diameter of laterals compared with the control. An exception was the BA 400 × 3–5 sprays. Apparently, these latter sprays resulted in weaker laterals, even though they formed as many laterals as the other BA treatments. The angles of lateral crotches in the BA treated trees were consistently wider (between 70° and 85°) than those of the control trees (45°). Heights and stem diameters of BA treated trees were slightly lower than the control trees. However, the difference was not commercially

important (data not shown). Lateral shoots seemed to be well distributed along the stem at lower BA concentrations (200 mg l^{-1}) with fewer treatments (personal observation).

DISCUSSION

Even under good nursery management, many cultivars of a wide range of fruit trees branch inadequately (Quinlan and Tobutt, 1990). Similarly, the Mondial Gala / MM.106 combination produces vigorous nursery trees with few laterals. Lateral shoot formation differs among cultivars with the apical dominance of a given cultivar (Faust, 1989). The rootstock also seems to play an important role in the branching pattern of the scion (Warner, 1991). Further, not only the rate, but also the type of active ingredients of any chemical, could be important in the branching process (Gastol and Poniedzialek, 2003). These results support the need for branch inducement research with different scion cultivars, rootstocks and chemicals to obtain well-feathered trees.

In the present study, the BA treatments were significantly effective in stimulating lateral shoot (feather) development in the Mondial Gala / MM.106 combination. Our results are in accordance with previous work on apples conducted with BA or Promalin (benzyladenine + GA_{4+7}) sprays (Cody et al., 1985; Hrotko et al., 1996). It was reported that the effect on branch numbers of equal concentrations of BA alone and Promalin were similar, with speculation that the small positive effect might not be sufficient to justify the cost of Promalin (Cody et al., 1985). Therefore, the choice of chemicals may be affected by their cost and availability.

The total number of laterals per tree was considerably higher with the BA treatments than with the control trees, which confirmed the positive effect of the chemical. Although all BA treatments increased the number of laterals in the 30–50 cm length class (3 to 5), the diameters of the laterals were different. BA 400 × 3–5 sprays resulted in lower lateral diameters. These weaker laterals may not be good for tree shaping. An average of two laterals with a good diameter were also obtained in the 10–30 cm length class with BA 200 treatments. Therefore, BA 200 treatments can be considered better for obtaining good laterals for tree shaping than BA 400 treatments. Choosing a low concentration in this rootstock × scion combination would be beneficial in reducing chemical input. Repeated BA treatments tended to produce more laterals than a single treatment, although the difference was not statistically significant. Nevertheless, 2–3 sprays could be better for obtaining the desired effect of BA 200 under nursery conditions because repeated BA sprays were reported to improve BA absorption in previous studies (Wertheim and Estabrooks, 1994; Hrotko et al., 1996).

Total length of laterals in BA sprayed trees was significantly increased, primarily because of an increased number of laterals. In general, the average length of laterals per tree with most BA treatments was good (over 40 cm). However, a reduction was detected with BA 200 × 1–3 sprays, although they were still at commercially acceptable levels. A reduction in lateral length with BA was previously reported in young apple trees at a concentration of 500 mg l^{-1} BA (Miller, 1985). In Bradford pear lines, a reduction in shoot length was most evident for BA at concentrations ≥ 450 mg l^{-1} (Keever et al., 1993). In our study, the reduction in average lateral lengths with a low BA concentration (200 mg l^{-1}) might have resulted from a relative increase in the total number of laterals per tree rather than from a negative effect of BA. This was because there were no such decreases with other BA treatments in this study. The BA treatments significantly increased the crotch angle of lateral shoots, a result that agrees with earlier reports (Cody et al., 1985; Keever et al., 1993). Wide crotch angles are important for forming strong unions between limbs and the trunk. Lateral shoots seemed to be well distributed around and along the stem at lower BA concentrations (200 mg l^{-1}) with fewer treatments (up to three sprays), whereas, at higher concentration (400 mg l^{-1}) or more treatments (four or five sprays), trees seemed to have a bushy appearance with closely spaced laterals (personal observation). Costes and Guédon (1989) demonstrated that sylleptic shoots were more numerous in the median zone of the stem of Gala apples compared with the other apple cultivars. This tendency might have been pronounced with a higher concentration or greater number of applications of BA and led to a more or less bushy appearance. The exogenously applied BA might have influenced the internal BA contents of the buds, and thereby caused the different branching pattern. This was noted by Cook et al. (2001), who investigated the possible relationship of branching habit to cytokinin content of apple shoots and suggested that the differential distribution of cytokinin reflects the pattern of budburst and may be correlated with growth habit.

Additionally, it was reported that the vigour of a particular cultivar × rootstock combination, as well as vigour-inducing conditions such as a warmer climate and longer growing season might play a major role on the effectiveness of the branch inducing techniques (Ouellette et al., 1996). Accordingly, these factors might have contributed to much of the branching under our conditions. More recently, Gastol and Poniedzialek (2003) stressed the important role of environmental conditions in the induction of sylleptic shoot formation with branching agents. So, they obtained different branching results in a three-season study. Fortunately, in the present study, the nursery was located in favourable growing conditions that would not change much from year by year, and both the scions and rootstocks were vigorous. Under favourable growing conditions, relatively vigorous growth of the rootstock-scion combination in semi-dwarf apple nursery trees may ease lateral branching with BA treatments. In our study, two

or three sprays of BA at 200 mg l^{-1} in mid-June seemed to be sufficient to form at least four strong laterals (30–50 cm) along with two medium-strength laterals (10–30 cm) in the Mondial Gala / MM.106 apple nursery trees.

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