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Effect of Length of Cuttings, Substrate pH and Mineral Nutrition on Rooting of *Pyrus communis* Cultivars

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Summary

Cultivars of the genus *Pyrus*, commonly known as pear, are generally propagated, by budding on rootstocks. *Pyrus* cvs. on their own roots may overcome the problems of *Pyrus* cvs. on the often used quince rootstock in calcareous soils and the problem of poor winter hardiness. Because small cuttings are difficult to root, at the first time investigations on propagation of long cuttings (100 cm) of *Pyrus* cultivars were initiated. The influence of pH and application of a slow release fertilizer on rooting in *Pyrus communis* cv.'Williams Christ' long cuttings was investigated. The highest rooting percentage was observed at a pH of 5.7 in the substrate, while application of 2 kg m^{-3} Plantacote Mix 4M® was optimal for rooting. The pH of the substrate affected the root number and the length of the roots. Use of Plantacote Mix 4M® did not improve root length. The pH of the substrate and the use of slow release fertilizer influenced the length of side branches.

The influence of apical and basal position and length of cuttings on rooting properties of *Pyrus communis* cv. 'Conference' was studied in an unheated greenhouse experimental set-up. The length of cuttings did not significantly affect rooting percentage. Cuttings taken from the basal parts had higher rooting than cuttings from apical parts. Long cuttings tended to have the highest number and length of side branches per cutting.

Most of the rooted long cuttings develop flower buds before transplanting in the field.

Loss of rooted cuttings due to poor overwintering is a common problem in many nurseries. The effect of two overwintering methods on subsequent field establishment was studied. Field establishment of rooted *Pyrus* cv. cuttings was more successful after leaving the cuttings in an unheated greenhouse in winter and planting out in spring as compared to field planting in autumn.

Zusammenfassung

Einfluss von Stecklingslänge, pH-Wert und Aufdüngung des Substrates auf die Bewurzelung von *Pyrus communis*-Sorten. *Pyrus communis*-Obstsorten werden generell über Okulation auf Unterlagen vermehrt. Birnensorten auf Quitte okuliert wachsen schlecht auf alkalischen Böden und zeigen mangelnde Winterhärte. Sorten auf eigener Wurzel könnten diese Probleme lösen. Da Kurzstecklinge von Birne schwerer vermehrbar sind, wurden zum erstenmal Untersuchungen zur Vermehrung von Birnensorten über Langstecklinge (100 cm) durchgeführt. Es wurde der Einfluss von pH-Wert und Aufdüngung des Stecksubstrates mit Depotdünger auf die Bewurzelung von *P. communis* 'Williams Christ' Langstecklingen untersucht. Das beste Bewurzelungsprozent wurde bei pH 5.7 und Applikation von 2 kg m^{-3} Plantacote Mix 4M® erreicht. Der Substrat-pH-Wert beeinflusst die Wurzelzahl und die Wurzellänge. Plantacote Mix 4M® beeinflusst die Wurzellänge nicht. Substrat-pH und -aufdüngung beeinflussen die Länge von Seitentrieben.

In einem unklimatisierten Foliengewächshaus wurde der Einfluss der Stecklingslänge und -position (apikal/basal) auf die Bewurzelung der Birnensorte 'Conference' untersucht. Die Länge der Stecklinge beeinflusst den Prozentsatz der Bewurzelung nicht signifikant. Basalstecklinge verschiedener Länge zeigen bessere Bewurzelung als Terminalstecklinge. Langstecklinge haben die höchste Anzahl und Länge von Seitentrieben.

Die meisten bewurzelten Langstecklinge haben noch vor dem Auspflanzen Blütenknospen gebildet.

Das Absterben von bewurzelten Stecklingen während der Überwinterung ist ein bekanntes Problem. Der Einfluss von zwei Überwinterungsmethoden auf das Überleben nach der Verschulung wurde untersucht. Dabei war das Überleben von Stecklingen, die im unbeheizten Gewächshaus überwintert und im Frühjahr verschult wurden, besser als nach Herbstverschulung.

Key words. pear cultivar – long cuttings – fertilization – pH – overwintering

Introduction

Budding and grafting are the most commonly used propagation methods for almost all European (*P. communis* L.) and Asian (*P. pyrifolia*) pears grown in commercial fruit production. *Pyrus* cvs. on their own roots may overcome the problems of *Pyrus* cvs. on the often used quince rootstock in calcareous soils and the problem of poor winter hardiness. A few scion cultivars such as *P. communis* 'Conference' can be propagated on

their own roots by small conventional cuttings but this option has not been adopted commercially (WEBSTER 1998), because propagators have experienced varying rates of rooting success from year to year. Hence, research efforts have continued over the years to improve the rooting potential of these cultivars. Propagation by cuttings would be considerably cheaper and faster than grafting or budding (HARTMANN et al. 1997). Micropropagation has also been explored but the costs of plantlets are three times higher than rooted cuttings (OSTERC and SPETHMANN 2000).

Current developments at the Tree Nursery Science Section, University of Hanover (Germany) have shown greater rooting with long cuttings (60–100 cm) compared to the conventional nodal cuttings (10–25 cm) in Q*uercus robur, Acer platanoides, Rosa canina* and some other species (SPETHMANN and HUHN 2001; SPETHMANN 2003). SPETHMANN (2002) demonstrated that long cuttings of *Pyrus communis* cv. 'Williams Christ' attained 60–80 % rooting and when established in the field started flowering seven months after rooting. Thus, there was a need to conduct investigations to establish the effect of length and cutting position on rooting percentage and quality of *Pyrus* cuttings.

Substrate pH and mineral nutrition are important factors that influence rooting and further growth of the cuttings (MLASOWSKY 1996). For *Quercus,* substrate pH of 3.5–4.5 and fertilization with 2 kg m^{-3} Osmocote Plus® (3–4 months) tended to stimulate shoot growth effectively and resulted in shorter production time (SPETHMANN 1998). It was therefore intended to establish a favourable substrate pH and amount of slow release fertilizer for rooting of *P. communis* cultivars.

The method of overwintering rooted cuttings is important in woody plants. Various overwintering methods can be applied with an ultimate goal of achieving high survival of rooted cuttings after the winter period and continued growth after field establishment. Autumn planting could improve establishment and better growth in the following spring, but winterhardiness of rooted cuttings often is low.

Materials and Methods

Plant material

Pyrus cv. cuttings were obtained from the crown region of 25–37 year-old fruit orchards in the middle of July 2002. Long water shoots (80–120 cm long) of that current year were used. Every treatment consists of 4 replications each of which had 25 cuttings in a completely randomised design.

Fertilization and pH of the substrate

Three levels (0, 2 and 4 kg m^{-3}) of slow release fertilization by using Plantacote Mix 4M® (10-10-15-3 MgO plus Trace elements) and four pH levels (3.0, 4.0, 5.0 and 6.0) were tested in a two-factor experiment using *P. communis* cv. 'Williams Christ' (Table 1). The fertilizer was incorporated in the substrate (peat:sand, 3:1, v:v) during mixing. The pH was adjusted by calcium carbonate ($CaCO_3$). No $CaCO_3$ was added for pH 3 (Table 1).

The long cuttings (60–120 cm) were treated with 0.5 % Indole butyric acid (IBA) (with 10 % Euparen on talcum basis) and placed in ground beds in a plastic greenhouse. The greenhouse was fitted out with a high-pressure fog system with a humidity of 95–100 %. There was neither temperature control nore bottom heating.

Cutting sections of different length for cultivar 'Conference'

Cuttings were prepared into five shoot sections of different lengths (Fig. 1). Shoot section A (0–100 cm) represented the full cutting length, approximately 100 cm long. B_1 (25–100 cm) and B_2 (0–25 cm) of 75 cm and 25 cm respectively and C_1 (50–100 cm) and C_2 (0–50 cm) each of 50 cm were obtained from A. Cutting sections B_1 and C_1 were referred to as apical cuttings while cuttings sections B_2 and C_2 were referred to as basal cuttings, respectively. The cuttings were treated as described earlier and placed in rooting beds containing a peat and sand mix (3:1/v:v), with an added 2 kg m^{-3} Plantacote Mix 4M® slow release fertilizer.

Overwintering of rooted cuttings

Further 450 cuttings were rooted in 1 litre containers and planted in the field in two batches. The first batch was planted in autumn while the second batch remained in the unheated plastic greenhouse over the winter period and planted out in spring. Temperatures in the greenhouse are similar to outside, but the plants are sheltered.

Table 1. Experimental treatments for pH (in July) and Plantacote Mix 4M® (in brackets realized pH in September).

Plantacote Mix 4M® (kg m^{-3})	pH 3.0 (3.8)	4.0 (4.9)	5.0 (5.7)	6.0 (6.8)
0	T 1	T 4	T 7	T 10
2	T 2	T 5	T 8	T 11
4	T 3	T 6	T 9	T 12

T = Treatment

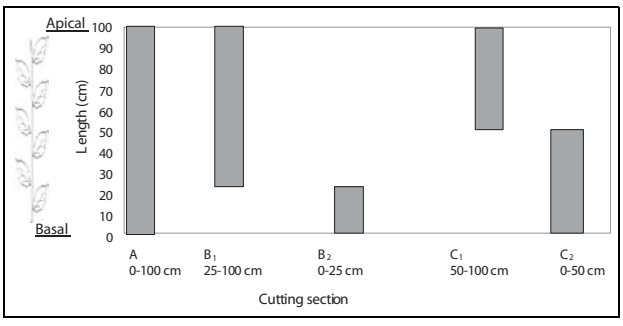


Fig. 1. Cutting length and position of cutting sections for *P. communis* cv. 'Conference' cuttings.

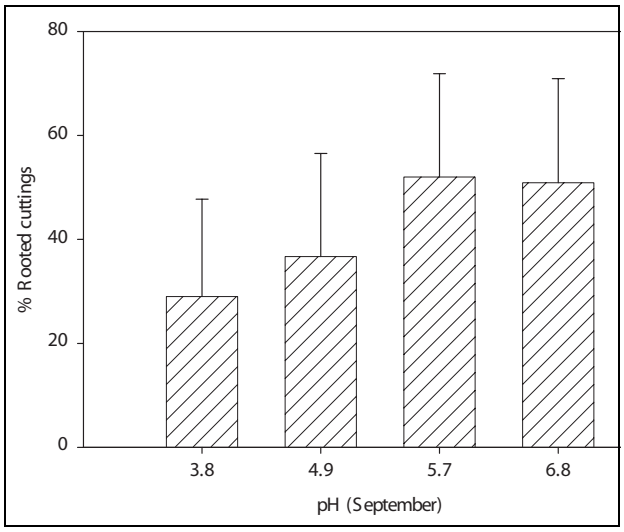


Fig. 2. Effect of the pH of the substrate on rooting percentage in *P. communis* cv. 'Williams Christ' cuttings. Vertical bars indicate standard deviation.

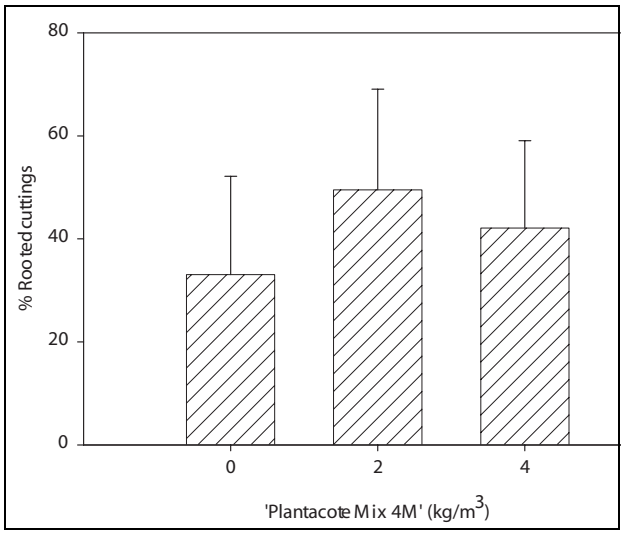


Fig. 3. Effect of Plantacote Mix 4M® on rooting percentage in *P. communis* cv. 'Williams Christ' cuttings.

Observations

Rooting response was assessed in October 2002 and in March 2003. The numbers of roots per cutting and the length of the longest root per cutting were determined. The effects of the different root quality factors such as rooting percentage, length of terminal shoots, number and length of side branches were analysed.

The data were subjected to an analysis of variance (ANOVA) using the generalised linear models (PROC GLM) procedure of the Statistical Analysis System (SAS 2002) program package. If ANOVA was significant multiple comparisons among means were done using Tukey's student range test (HSD) at α=0.05.

Results

Effect of Plantacote Mix 4M® and the pH of the substrate on rooting of P. communis *cv. 'Williams Christ'*

All pH levels increased during the season (Table 1). Substrate pH had a significant effect on rooting percentage (Fig. 2). A higher substrate pH tended to favour rooting; more than 50 % rooting was obtained at substrate pH 5.7 and 6.8.

Plantacote Mix 4M® had a significant effect on rooting percentage (Fig. 3). Application of 2 kg m^{-3} gave the highest percentage rooted cuttings and decreased with use of 4 kg m^{-3}.

The pH of the substrate had a significant effect on the number of main roots per cutting (Table 2). Substrate pH of 3.8 tended to have the highest number of main roots per cutting while the lowest was at substrate pH of 4.9.

Substrate pH influenced the length of longest root per cutting (Table 2). Substrate pH of 5.7 and 6.8 had significantly longer roots compared to substrate pH of 3.8.

Interactions between fertilizer and pH-treatment could not be found.

Table 2. Effect of pH and Plantacote Mix 4M® on number of main roots and root length of *P. communis* cv.'Williams Christ' cuttings.

pH	Number of main roots per cutting	Length of longest root/cutting (cm)
3.8	7.71 a	13.88 b
4.9	4.62 b	15.38 ab
5.7	6.58 ab	16.86 a
6.8	5.72 ab	16.91 a

Mean with same letter in the column are not significantly different. (Tukey's Student test α=0.05)

Table 3. Influence of pH and Plantacote Mix 4M® on length of terminal shoot, number of side branches and the length of the longest side branch in 'Williams Christ' cuttings.

pH	Length of terminal shoot/ cutting (cm)	Length of side branch/ cutting (cm)	No of side branches/ cutting
3.8	8.39 a	9.73 b	1.91 a
4.9	10.84 a	11.46 b	1.81 a
5.7	10.34 a	12.25 ab	1.90 a
6.8	11.18 a	14.37 a	2.26 a
Plantacote Mix 4M® (kg m^{-3})			
0	8.78 b	10.79 b	1.74 a
2	9.63 b	12.40 ab	2.18 a
4	12.37 a	13.29 a	1.93 a

Mean with same letter in the column are not significantly different. (Tukey's Student test α=0.05)

Side branches were significantly longer at substrate pH of 6.8 compared to substrate pH of 3.8 and pH 4.9 (Table 3). The pH of the substrate did not affect the length of terminal shoots and number of side branches.

Application of slow release fertilizer enhanced the length of terminal shoots and length of side branches but not the number of side branches per cutting (Table 3).

Effect of stem section and length of cuttings on rooting of P. communis *cv. 'Conference' cuttings*

The length of cuttings had no significant effect on rooting percentage (Fig. 4). A higher rooting percentage was observed in cuttings with the basal part (B_2 and C_2) compared with apical parts (B_1 and C_1).

Cuttings from section A (0–100 cm) had a significantly higher number of side branches compared to sections B_2 (0–25 cm) and C_1 (50–100 cm) (Table 4).

Similarly, cuttings sections A (0–100 cm) had significantly longer side branches per cutting than sections B_1 (25–100 cm) and B_2 (0–25 cm).

Overwintering of P. communis *cv. 'Williams Christ' rooted cuttings*

There was no overwintering loss of cuttings in the unheated plastic greenhouse. In spring, 4 % of the rooted cuttings had shoot die-back. Additionally, about two thirds of the rooted cuttings formed flower buds in the greenhouse.

In June 2003 (after the frost period), only 26.7 % of the cuttings transplanted in autumn survived compared to 64.4 % for those planted out in spring (Table 5). The cuttings planted out in spring had better shoot growth with respect to the number of sprouted buds and growth of new terminal shoots.

Discussion

Effect of Plantacote Mix 4M® and the pH of the substrate on rooting of P. communis *cv. 'Williams Christ'*

Higher substrate pH (5.7, 6.8) levels favoured root development of cuttings (Fig. 2). The pear cultivar 'Williams Christ' seems to be adapted to this pH range. JACKSON and PALMER (1999) indicated that the best pH range for growth of pears in orchards is 5.5–6.5 and in some circumstances from 4.5–8.0. In species such as oak that grow in acid soils in nature, lower substrate pH values (3.2–4.5) are favourable giving better rooting, higher root numbers and superior shoot growth (SPETHMANN 1998). For cherry rootstocks, the best rooting was achieved at a higher pH level of 7.3 (OSTERC and SPETHMANN 2000). Decreasing rooting medium pH corresponded with improved rooting of Blue Girl holly (BRIAN 2000). These reports indicate that the conditions of optimal pH depend on individual species and tolerances may vary among species and genera.

The rooting percentage of *P. communis* cv. 'Williams Christ' (Fig. 3) was highest with 2 kg m^{-3} Plantacote Mix 4M® as recommended by (MAC CARTHAIGH and SPETHMANN 2000). These results confirm that the use of slow release fertilizer showed a positive effect on rooting percentage and shoot growth (PRZERADZKI and MAC CARTHAIGH 1988). Application of 0.4 g Nl^{-1} (2 kg m^{-3} Osmocote plus®) resulted in highest rooting of cherry rootstock cuttings (OSTERC and SPETHMANN 2000). The application of slow release fertilizer enhanced both root and shoot development in *Ligustrum japonicum* while high rates of application delayed the rooting of cuttings (HARTMANN et al. 1997).

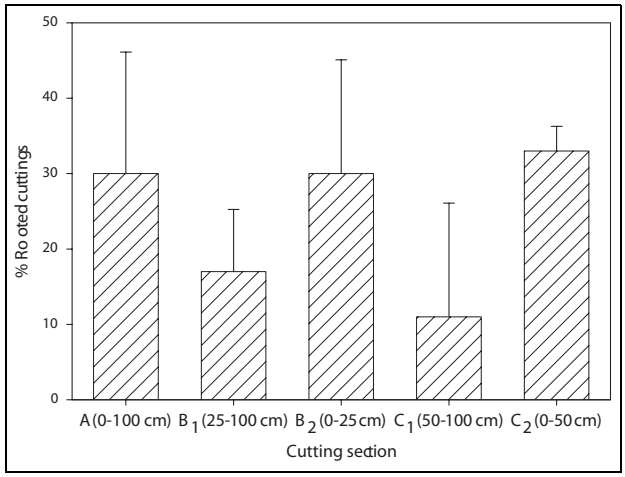


Fig. 4. Effect of cutting section and length of cutting on rooting percentage of *P. communis* cv. 'Conference' cuttings. Vertical bars indicate standard deviation.

Table 4. Effect of cutting section and length of cuttings on shoot parameters in rooted *P. communis* cv. 'Conference' cuttings.

Cutting section	No of side branches	Length of the longest side branch/cutting (cm)
A (0 – 100 cm)	2.79 a	12.64 a
B_1 (25 – 100 cm)	2.22 ab	6.78 b
B_2 (0 – 25 cm)	1.29 b	6.71 b
C_1 (50 – 100 cm)	1.00 b	9.00 ab
C_2 (0 – 50 cm)	1.81 ab	9.44 ab

Mean with same letter in the column are not significantly different. (Tukey's Student test α=0.05)

Table 5. Effects of different overwintering methods on field establishment of *P. communis* cv 'Williams Christ' cuttings for field assessment made in May and June 2003, n=45.

Response (%)	May 2003		June 2003	
	Time of transplanting			
	Autumn	Spring	Autumn	Spring
Survival	64.44	91.11	26.67	64.44
Cuttings with new shoot	22.22	55.56	6.67	44.44
Cuttings with flushed buds	26.67	71.11	26.67	64.44

Effect of stem section and length of cuttings on rooting of P. communis *cv. 'Conference'*

Basal cuttings of of *P. communis* cv. 'Conference' (Fig. 4) tended to have higher rooting than apical cuttings probably because of the positional differences on the cuttings (topophysis effect) and distribution of starch and other carbohydrates within the cuttings (HARTMANN et al. 1997). Carbohydrates serve as an energy source and deliver the needed carbon skeletons for new metabolites for the rooting process (VAN'T HOFF 1968). Rooting requires rapid metabolism of stored reserves and for cuttings to survive, they must be able to replace used up carbohydrates (VEIERSKOV 1988).

The number of root initials in woody stems (in some species) distinctly decreases from the base to the tip of the shoot (HAISSIG 1972).The rooting capacity of basal portions of such shoots would be considerably higher than that of the apical parts. Such changes could be attributed to the accumulation of natural auxins or other promoters (HARTMANN and HANSEN 1958), relatively low levels of rooting inhibitors (PATON et al. 1970), and hypothetical juvenility factors (BONGA 1987). The production and distribution of growth hormones in the long and short cuttings has not been investigated.

Apical cuttings rooted poorly probably due to factors such as bud development and hormonal level. Since apical cuttings are usually softwood or semi-hardwood cuttings that have a developing apex and associated young leaves, which may produce rooting promoters (HARTMANN and BROOKS 1958). However, they could be inhibitory if their sink activity is excessive (FISCHER and HANSEN 1977). In contrast, long terminal cuttings of *Rosa canina* had higher rooting compared to the long and short basal cuttings (SPETHMANN 2001).

The higher number and length of side branches on long cuttings (Table 4) indicate the possibility that these cuttings could undergo better establishment and development.

Overwintering of P. communis *cv. 'Williams Christ'*

There was no loss of rooted cuttings during overwintering in the unheated greenhouse in this study. SPETHMANN (1986) reported 2–4 % loss of *Quercus* rooted cuttings while overwintering in an unheated greenhouse. Survival and field establishment was more successful with plants overwintered in an unheated greenhouse and spring planted compared to planting out directly in autumn. Planting in autumn may have resulted in root damage; hence the chances of successful field establishment were low since the plants were not protected from frost, drying, and other injurious weather conditions. In roses however, transplanting in autumn gave high survival after field planting (SPETHMANN and HUHN 2001).

Flowering of P. communis *cv. rooted cuttings*

The flowering of rooted *Pyrus* cv. cuttings in spring was consistent with work by SPETHMANN (2002). Flowering in *Pyrus* rooted cuttings could have resulted due to the advanced age of the stock plants that were used. This observation was unexpected, as vertically oriented water shoots do not form flowers when they remain on the tree. One explication could be that the cuttings underwent stress as a result of high temperatures and high humidity during rooting which subsequently caused early flower formation. Different kinds of stress (high temperatures, water stress, root pruning) during time of flower induction induce flowering in *Picea*, *Pseudotsuga* and *Betula* seedlings before they reach the adult stage (KLEINSCHMIT et al. 1980).

The physiological condition of flowering means that the plant has passed from the vegetative to the generative stage. This phenomenon is common in fruit cultivars on dwarfing rootstocks (M9, *Prunus* 'Gisela') implying weak shoot growth. If this can be confirmed, it could be interesting to exploit this phenomenon by producing cheaply and fast "small" self rooted *Pyrus* plants for gardeners and growers.

Additional trials are being conducted to compare the growth of these self-rooted long cuttings with *Pyrus* budded on Quince and seedling rootstocks. Results so far indicate that the self-rooted pears from long cuttings remain smaller compared to the *Pyrus* budded on Quince or seedlings. This suggests that an early maturing and aging effect resulting from the use of long cuttings may impart early flowering. Observations in the next years will show if the long cutting will start to grow faster like the long cuttings of *Acer platanoides* and *Ulmus* 'Regal' and *Quercus robur* (SPETHMANN 2003). The performance of self-rooted long cuttings will be clear after extensive trials have been conducted.

Conclusions

At the first time propagation of *P. communis* cvs. by long cutting was investigated. In order to obtain planting material of uniform size, it is necessary to standardize the cutting material for propagation. Short terminal cuttings should be avoided. Propagators could benefit from using long cuttings by reducing the propagation time and costs. Long cuttings show better root and shoot quality than small cuttings.

Rooting of *P. communis* cv. 'Williams Christ' is improved when cuttings are placed at a pH of 5.7–6.8 in the substrate. Use of Plantacote Mix 4M® at 2 kg m^{-3} is recommended. The use of slow release fertilizer improved both the root and shoot parameters of rooting cuttings.

Transplanting *P. communis* cv. 'Williams Christ' rooted cuttings in autumn resulted in low survival after field establishment. The overwintering in an unheated greenhouse and spring planting resulted in higher survival of the rooted cuttings after field establishment.

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