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Effects of Microtopography on Fruit Production of Strawberry, *Fragaria chiloensis* Duch. var. *ananassa* Bailey

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Abstract

The effect of microtopography on fruit production of *Fragaria chiloensis* var. *ananassa*, a cultivated strawberry, was investigated on a poorly drained field with a clayey soil; there was a 0.23-m difference in altitude with reference to soil water conditions. The number of fruits produced by plants at the highest altitude site was higher than at elevations 0.11 m and 0.23 m below this: the number decreased with decreasing altitude. Root system development at the lowest site was shallower than at the other sites. Although precipitation was intercepted by construction of a greenhouse, the soil water potential at the lowest site still remained>-10 kPa at 0.30 m depth during the fruit production stage. The development of the root system was inhibited by the high water content of the surface soil, and thus the production of fruit was also inhibited. The slight difference (0.23 m) in microtopography caused a large difference in fruit production on this poorly drained field.
Key words: photosynthesis, poor drainage, soil water potential, strawberry, water table

Introduction

The physiological properties, vegetative growth and reproduction of plants are affected by soil water conditions[1-4]. In fields with clayey soils, poor drainage usually prevents crops from growing well. Many field crops have a low tolerance to flooding because of the poor development of aerenchyma, a structure which is common in rice and other wetland species[5-6]. The crops are therefore vulnerable to short-term flooding or a slight rise in the ground-water table. The most important management procedure in poorly drained fields is to improve the drainage by constructing drainage systems or to lower the depth of the water table by dressing the soil with highly water permeable soils (*e.g.* volcanogeneous regosols). However, it still remains difficult to establish the most effective procedure to improve fields with poor drainage.

This study aimed to evaluate how a microtopographical difference of 0.1–0.2 m influences fruit production of *Fragaria chiloensis* Duch. var. *ananassa* Bailey (cultivated strawberry) in poorly drained fields with special reference to soil water condition and root development.

Materials and Methods

The study field (area 0.33 ha) is located in Toyoura, S-W. Hokkaido, Japan (42°36′ N, 140°38′ E). The annual mean temperature for the period, July 1995 to June 1996, was 7.3 °C and annual precipitation was 1321 mm (data from the nearest meteorological observatory at Ogishi). Six conduit pipes were buried about 1 m below the present soil surface and the effluent from the pipes was collected by a drainage ditch. The altitude of the field was about 6.5 m a.s.l., where a side end with a ditch was 0.53 m lower than the other side without a ditch. A greenhouse was located parallel to the altitudinal gradient. The soil of the area is classified as lowland alluvial with fine texture: Eutric Fluvisol[7]/Typic Fluvaquent[8].

The strawberry cultivar 'Houkou Wase' was planted on 3 September 1995. A greenhouse covered with vinyl chloride sheet was constructed in early December 1995. This was 6.4 m wide and 53.0 m long, and four beds (bed width 0.9 m, inter-bed width 0.6 m) were prepared in the greenhouse. Strawberry plants were planted in two rows (between rows 0.30 m, inter plants 0.27 m) on each bed. The density was 43,570 plants ha^{-1}. Chemical fertilizer (150 kg ha^{-1} nitrogen, 157 kg ha^{-1} phosphorus and 145 kg ha^{-1} potassium) was applied before planting. Plants were grown without temperature control or irrigation.

The depth of the water table below surface, soil water potential and soil temperature were all monitored at three sites along the altitudinal gradient, where site A was about 0.23 m, and site B was about 0.12 m higher than the site C. Each plot was 68 m^2.

The water-table depth was measured from 14 September 1995 to 15 May 1996. A vinyl chloride pipe (30 mm diameter, 2.0 m long) with holes (7-mm diameter) at 0.10-m intervals was inserted vertical to the soil surface to a depth of 1.50 m at each site. Measurements were made daily during September, and then on the 1st and 15th of every month from October to May. Tensiometers for soil water potential measurements were established at depths of 0.10, 0.20, 0.30, 0.40 and 0.50 m at each site, and the water potential was measured at the same time as the water table. Soil temperature was measured at depths of 0.10, 0.20 and 0.30 m from 1 November 1995 to 15 May 1996 on the 1st and 15th of every month.

The harvest of mature fruit began on 15 April 1996, and then all mature fruit was harvested at one- to three-days intervals until 31 May 1996. Production of matured fruits terminated at the end of May. The number of harvested fruits was counted at each site. The fresh weight of 25 randomly selected fruit was measured on 12 May 1996.

The photosynthetic rate was measured *in situ* on 29 May 1996. An infrared

carbon dioxide analyzer equipped with a Parkinson leaf chamber (Shimadzu Co., Japan SPB-H2) was used for the photosynthesis measurements. One leaf of the canopy of the strawberry population was selected at the center of each site, and net photosynthetic rate and respiration rate were measured by changing the photon flux density using nylon nets. About 20 measurements were made on each leaf.

The vertical distribution of root dry weight was measured on 1 August 1996. By this time, growth of the plant had completely stopped, and hence we obtained the final distribution of roots in the study plots. A 0.30 m×0.30 m quadrat for root sampling was located at the center of each investigation site, and soil with roots was collected at each 0.10 m depth. Roots were selected and dried at 75 °C for more than 2 days, and the dry weight was measured.

Results

1. Soil environment

The average soil temperature during fruit setting (April-May) at 0.10, 0.20 and 0.30 m depths was 14.5 °C, 14.5 °C and 15.4 °C, respectively, and showed no significant difference between sites.

Before the construction of the green house (mid-September to early-December), the depth of the water-table at site B was the same as that at site C, and higher than at site A. Its depth at site A showed little fluctuation (Fig. 1). After construction of the green-house (after mid-December), the water-table at the

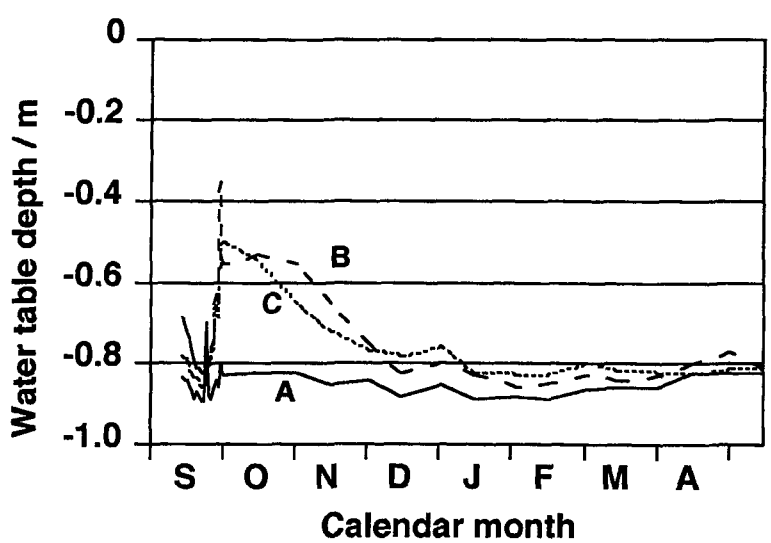

Fig. 1. Seasonal changes in water table depth at three sites in the investigation greenhouse. Relative altitude at site A is about 0.23 m and that of site B is about 0.12 m higher than that of site C.

three sites fluctuated little and the average water-table at site A was the lowest and that at site C was the highest, although the difference was less than 8 cm between the three sites. The depths of water-table below the soil surface reflected the topographical feature of the sites, although the difference in water-table was less than the difference in altitude.

The water potential in the soil was higher than -5 kPa at all three sites at depths from 0.10 to 0.50 m ; it began to decrease after January when the precipitation was intercepted by the vinyl chloride sheet at all the sites from early December (Fig. 2). A difference in soil water potential between the sites was obvious after late February. The decrease in soil water potential at site C was slower than at sites A and B, and the water potential was still higher than -10 kPa at 0.30 m depth until mid-May. Soil water potential at site C became lower than -10 kPa only at depths of 0.10 and 0.20 m, but became lower than -10 kPa at 0.30 and 0.40 m depths at sites B and A, respectively.

2. Fruit production

From the beginning of the harvest of mature fruit (15 April 1996) to 31 May 1996, the cumulative number of fruits harvested at site A was highest and that at site C was the lowest (Fig. 3). The cumulative fresh weight of fruits harvested from 15 April to 31 May in site A, B and C was estimated to be 11.88, 7.15 and 5.07 kg per 68-m^2 plot, respectively. The maximum number of fruits harvested per day was in late April at site A, early May at site B, and late May at site C. A delay in the production of fruits by plants at site C was evident.

3. Photosynthesis

Photosynthesis curves (net photosynthetic rate vs. photosynthetically active radiation : PAR, Fig. 4) showed that the net photosynthesis rate was not saturated under the cultivation conditions (measured under the vinyl sheet in full sunshine). The photosynthetic rate of plants at site C was slightly higher than at sites A or B above PAR=500 μmol m^{-2} s^{-1}.

4. Root system development

At sites A and B, roots developed to a depth of 0.40 m, but at site C mostly only to 0.20 m, with a few roots below 0.20 m. A large proportion of the roots was distributed in the top 0.10 m of soil (Fig. 5) at all sites.

Discussion

Fruit production of strawberry plants at the highest altitude site was highest and the value decreased with decreasing altitude (Fig. 3). The phenology of fruit production shows that the period of maximum fruit production at the highest altitude site was the earliest and that at lowest altitude was the latest (Fig. 3). With respect to photosynthesis, however, shows that the photosynthetic rate of

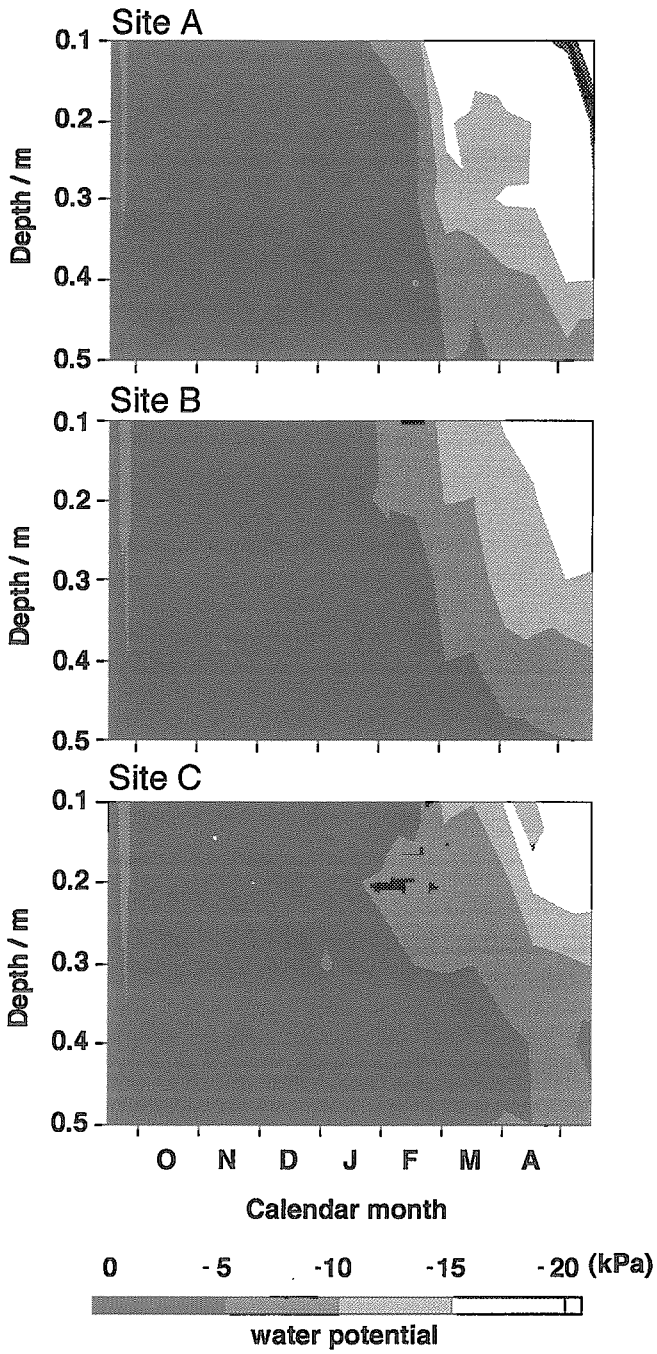

Fig. 2. Seasonal changes in vertical profile of soil water potential (kPa) at the three sites in the greenhouse. Potentials are categorized into every 5 kPa class. Vertical axis represents depth from the soil surface.

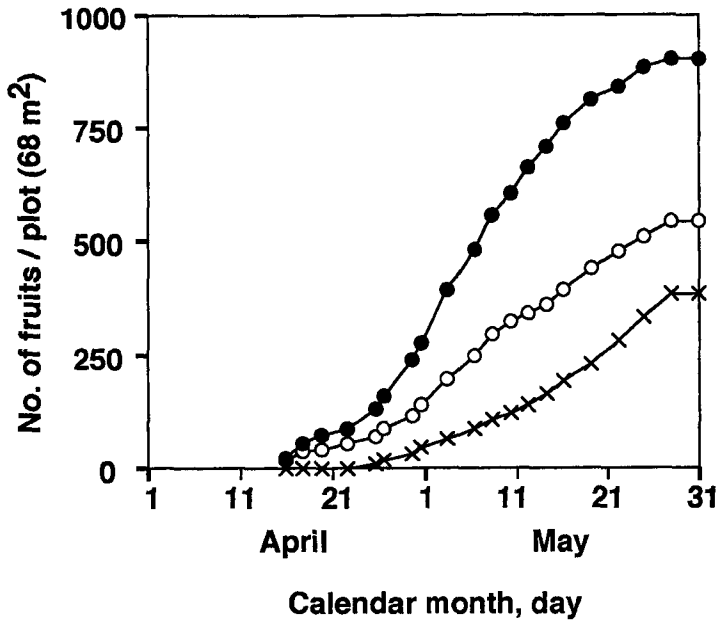

Fig. 3. Cumulative number of fruits of strawberry at site A (solid circles), site B (clear circles) and site C (crosses). Plot size was 68 m^2.

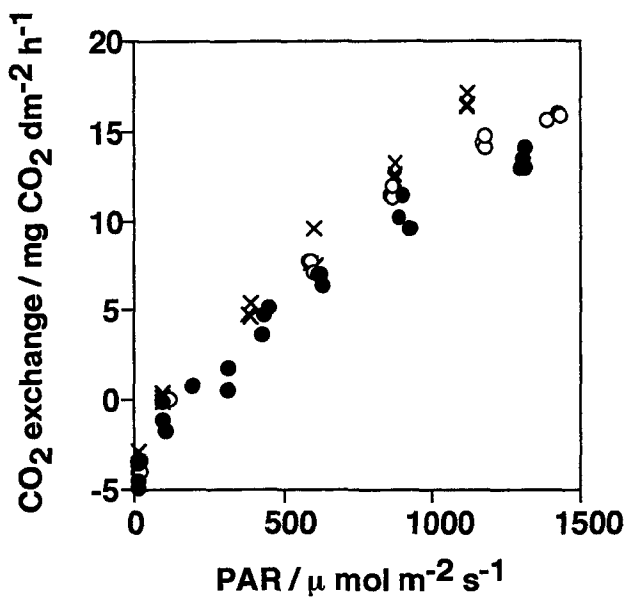

Fig. 4. Net photosynthetic rate of strawberry at site A (solid circles), site B (clear circles) and site C (crosses) in the greenhouse. Measurements were made on leaves at the center of each site on 29 May 1996.

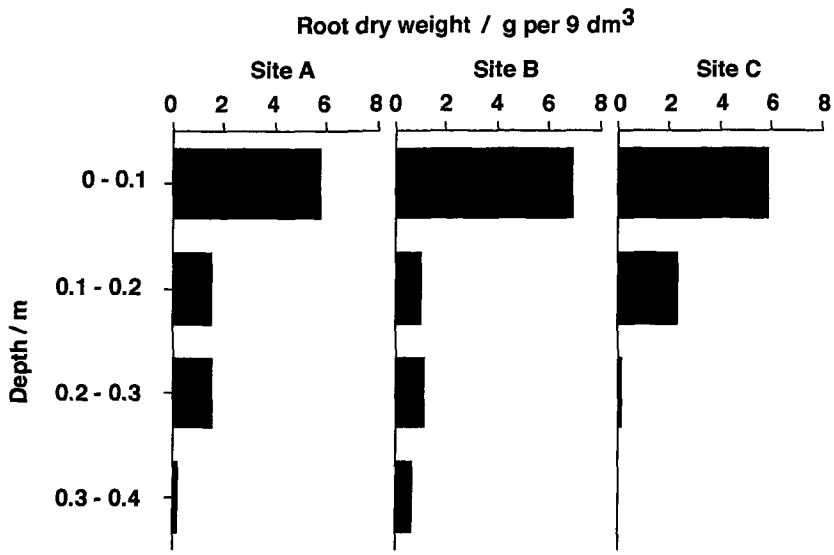

Fig. 5. Vertical distribution of root dry weight of strawberry at the three sites in the greenhouse.

plants at the lowest site was highest and that at the highest site was lowest, although the difference was not significant (Fig. 4). This implies that the photosynthetic potential of plants at the lower altitude site was kept as the same level as, or higher than the plants at higher altitude sites at least at the end of the fruit production (late May). The physiological activity of plants at the lower altitude sites was not inhibited by the higher soil water potential, so the lower fruit production at lower altitude sites was not due to a lower physiological potential than plants at higher altitude sites. The growth of plants at lower altitude sites was slower than that of plants at the higher altitude sites.

Why did plants at lower altitude sites show slower growth? The development of the root system at the lowest altitude site (site C) was far shallower than at A and B : roots at the latter were distributed to a depth of 0.30-0.40 m, whereas those at site C reached only 0.20 m depth. Honda[9] established that the optimal water potential in soil for the growth of strawberry is -3.1 to -9.8 kPa (pF=1.5 -2.0) during the vegetative growth stages, and -9.8 to -31.0 kPa (pF=2.0-2.5) during the flowering and fruit production stages. He also showed that the production of fruits increased from -3.1 to -9.8 kPa soil water potential, and that the higher water potential did not lead to higher fruit production. Our study showed that the maximum depth of root distribution corresponded to a depth at -10 kPa of soil water potential during the fruit production phase (after April). This implies that soil water conditions would affect root system development. Before the interception of precipitation, there was little difference in soil water

potential between the three sites (>-5 kPa). Soil water potential decreased gradually from January, one month after interception of precipitation by greenhouse construction. Although there was little difference in the water-table between the three sites (less than 8 cm from January to May), the decrease in soil water potential at site C was slower than at sites A and B, and the water potential was still higher at 0.30 m depth during fruit production. We assume that the slow decrease of the soil water potential probably caused the small root development, and thus the delayed fruit production at site C.

Although root distribution at site B was not so different from that at site A, the total number of harvested fruit at site B was about 60 % of that at site A. This was presumably due to the difference in soil water potential between sites A and B during the growing season. The soil water potential at depth 0.20-0.30 m at site A was below -10 kPa at the beginning of March, whereas that at site B became less than -10 kPa about one month later than site A. A phenological study on the differences in root development during the growing season between sites A and B would help to determine the cause of the difference in fruit production.

This investigation shows that a slight difference in microtopography and the consequent difference in soil water potential causes a great difference in the development and fruit production of the strawberry. A difference in microtopographical altitude of only 0.23-m caused a 2.3-fold difference in fruit production. A similar relationship between microtopography and plant growth was found by Haraguchi[10-12] in a study of a wetland community.

We found that the difference in water-table between sites did not always reflect the soil water potential, which was probably the most important parameter influencing fruit production in the poorly drained clayey soil field. We suggest that it is important to control precisely the soil water potential in soils of poorly drained fields.

Acknowledgments

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