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Effects of time and weeding method on the regeneration and growth of Japanese yam (*Dioscorea japonica*) vines and tubers in tea gardens

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ABSTRACT

For the weed control of Japanese yams, farmers pull out the vines by hand because the chemical control of Japanese yams in tea plantations is difficult as the vines grow from the area below the tea trees, where the herbicides have limited reach. This study compared the regeneration and growth of vines after controlling weeds using the following methods: 1) cutting the vine at 30 cm height, 2) cutting the vine at ground level, and 3) pulling out the vine from the base (at the node of the tuber and vine). All three treatments were performed during three weeding seasons to determine the most effective method and time to control Japanese yams in tea gardens. In addition, we investigated the deterioration of old tubers and the formation of new tubers by studying their weight changes because each old tuber disappears and forms a new tuber each year. However, our results indicated that new tubers were formed before the disappearance of old tubers, and there were no border time periods where both old and new tubers were absent. Furthermore, the new tubers grew in a short period from July to August. Therefore, we recommend repeatedly pulling out Japanese yam vines during July for effective weed control. Moreover, when vines of Japanese yam were not pulled out completely or were cut in May or July, branches grew rapidly and reached the canopy of tea trees after 2–4 weeks. Furthermore, when vines were pulled out at the ground level, 40 % of vines reached the canopy after one month. Therefore, it is difficult to control Japanese yam completely by pulling out vines alone.

Key words: Japanese yam (*Dioscorea japonica*), Vine weed, Tea garden, Tuber, Hand weeding

INTRODUCTION

Japanese yam (*Dioscorea japonica*) is a perennial plant of Dioscoreaceae that is widely found at forest margins and in forests in Japan (Hori, 1984). Traditionally, Japanese yam was collected from its natural habitat and used as food. Currently, it is cultivated as a local vegetable (Inagaki and Ishiwata, 2022). However, Japanese yam is the most troublesome weed species in Japanese tea gardens (Seo, 2012; Ichihara et al., 2020). The chemical control of Japanese yam is difficult because Japanese yam vines grow from the area below the tea tree. In addition, Japanese yam vines grow thickly on the canopy of tea trees and get mixed in during the tea harvest, reducing the quality of the tea. Currently, there is no effective method to control Japanese yam, and farmers have to pull out the vines from their base by hand, which is a laborious task (Japan Soil Association, 2012; Seo, 2016). In fact, weeding accounts for 10–20 % of the labor hours in the management of Japanese tea gardens (Obata, 1987). In organic farming tea gardens, weeding accounted for 80 % of the labor hours (Ichihara, 2020). However, although weeding of Japanese yams in tea gardens requires considerable time and effort, the effectiveness of the hand-pulling method of weed control for managing Japanese yams is unknown.

When the Japanese yam vine is pulled out from the root base, the vine comes off at the node between the base of the vine and the tubers, allowing the vine to be removed completely. However, because Japanese yams in tea gardens are entangled with the roots of the tea plants, it is not possible to remove the grown yam by pulling, even if the vine can be pulled out by pulling (Iinagaki and Ishiwata, 2022). Therefore, there is concern that the vines will regenerate from the remaining tubers. In addition, Japanese yam vines may get cut in the middle without being pulled out from the base. It is difficult to completely remove the vine from its base, especially if the vine is entangled with the tea plant or with other vines of Japanese yam. If the vine is cut in the middle, the severed vine remains under the canopy of the tea plant. In recent years, weeding machines

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have been developed to remove Japanese yam vines. Methods of harvesting vines at the surface of the canopy of tea trees and removing them by winding vines at the surface of the tea canopy have been employed in these machines. However, it is difficult to pull out the vines of Japanese yam from the base using these machines, and although the upper part of the vines on the picking surface can be removed, there is concern that vines may remain. Therefore, in this study, in order to clarify the effects on subsequent regeneration and growth of remaining vines, we investigated the regeneration and growth of Japanese yam vines 1) when vines were cut at the middle, 2) when vines were cut at the ground level, and 3) when vines were extracted from the base.

Hand weeding of Japanese yam is often done before the second tea harvest season in June or July (Japan Soil Association, 2012). This weeding is only intended to prevent Japanese yam vines from contaminating the tea leaves during tea harvesting. Therefore, it is unclear whether the control of the vines at this time is effective in suppressing the overgrowth of Japanese yams in tea gardens. The vines of Japanese yam grow with nutrients from the old tubers, and the old tubers lose nutrients and disappear. Subsequently, a new tuber is formed to accumulate the nutrients obtained through photosynthesis (Fujimura, 1989; Yoshida, 2019). In this way, Japanese yams grow larger tuber as they are renewed. This suggests that enlargement of the Japanese yam tuber could be effectively suppressed if the vines are pulled out after the wastage of the old tuber and before the new tubers are formed. Therefore, this study also investigated the timing of old tuber wastage and new tuber formation in order to determine the appropriate timing for pulling out the vines.

MATERIALS AND METHODS

Study area

This study was conducted in a test field and tea garden at the Center for Education and Research in Field Sciences, Shizuoka University (Kariyado, Fujieda city, Shizuoka Prefecture, Japan; 34°54'18.8" N, 138°16'19.7" E). Tea trees have been cultivated in this field using conventional farming methods since 1974.

Old tuber wastage and new tuber formation

Tubers (approximately 50 g weight, 20 cm length) obtained from Japanese yam propagules cultivated for one year were used in the experiment. On April 6, 2020, 10 tubers were buried in the test field at 30 cm intervals, and three posts were erected so that the vines would wrap around them.

Each of the five plants was dug up, and the weights of old and new tubers were measured on June 8, July 15, and August 3, 2020.

Effects of pulling out or cutting vines

Japanese yams growing naturally in three 6 m rows in a *'Yabukita*' tea garden were used for the experiment. Three weeding treatments were performed: 1) cutting the vines at 30 cm height, 2) cutting the vines at ground level, and 3) pulling out the vines at the base (at the node of the tuber and vine). One treatment consisted of five Japanese yam plants. Each treatment was performed on three days (three weeding seasons): May 29, July 20, and August 31, 2020. The percentage of vines reaching the canopy of tea trees was determined once a week.

RESULTS AND DISCUSSION

Old tuber wastage and new tuber formation

The weight of the old tubers decreased slightly on June 8 (Fig.1). During this time, small new tubers (less than 1 cm in size) were observed. About a month and a half later, on July 15, the weight of the old tubers was about half that of the planted weight, and the weight of the new tubers was the same as that of the old tubers. About another month and a half later, on August 31, the old tubers had decreased to less than 10 g in weight. In contrast, the new tubers had enlarged to a weight exceeding the 50 g weight of the old tubers at planting. Thus, while the size of old tubers decreased slowly, the new tubers grew in a short period of time. It has been reported that the growth of new tubers of Japanese yam is accelerated by short-day conditions (Sato et al., 1995; Shiwachi et al., 2000) and that new tubers grow rapidly from July to August under cultivation conditions (Naito, 1987). In this study, the timing of new tuber formation was consistent with that of the previous studies.

Moreover, vines of Japanese yam grow using nutrients from old tubers, and new tubers are formed to accumulate photosynthetic products (Hori, 1984). Therefore, if there is a border time period where the old tubers are exhausted, but the new tubers have not formed yet, it would be an appropriate time to control Japanese yams in the tea garden. However, this study revealed that new tubers formed before the old tubers were exhausted, and there were no border time periods where both old and new tubers were absent.

Effects of pulling out or cutting vines

When vines of Japanese yam were cut at 30 cm height in May, 40 % of the vines reached the canopy of tea trees after two weeks of the cutting treatment, and 100 % of the vines reached the canopy after three weeks (Fig.2 a). When vines of Japanese yam were cut at the ground level, no vine regeneration was observed until the third week after treatment, and 80 % of the vines reached the canopy after four weeks (Fig.2 a). When vines were pulled out at the ground level, only 30% of the vines reached the canopy five weeks after treatment (Fig.2 a).

When vines of Japanese yam were cut at 30 cm height in July, 40 % of the vines reached the canopy of tea trees after three weeks of the cutting treatment, and 80 % of the vines reached the canopy after three weeks (Fig.2 b). When vines of Japanese yam were cut at the ground level, 40 % of the vines reached the canopy of tea trees after two weeks of the cutting treatment. When vines were pulled out at the ground level, 40 % of the vines reached the canopy after five weeks (Fig.2 b). The direct damage due to Japanese yam is caused by the vines that thrive on the canopy of tea plants, contaminating the tea leaves during harvest. Therefore, there is not a direct problem if the vines of Japanese yam do not reach a height of 60–70 cm or less, which is the height of the tea tree canopy. However, our results showed that when vines of Japanese yam were cut or pulled out in May or July, the vines regenerated quickly and reached the canopy of tea trees in a short period of 2 to 4 weeks. In addition, cutting treatment or pulling treatment

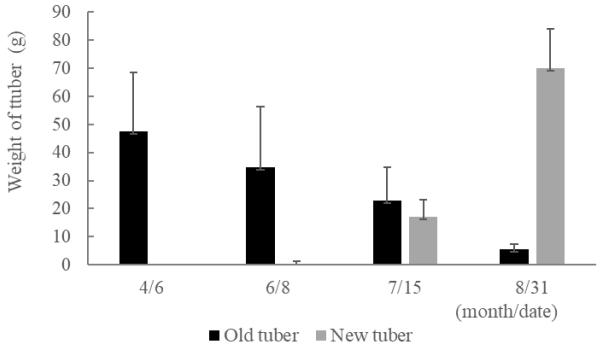

Fig. 1: Changes in the weight of old and new tubers. Error bar indicates standard deviation.

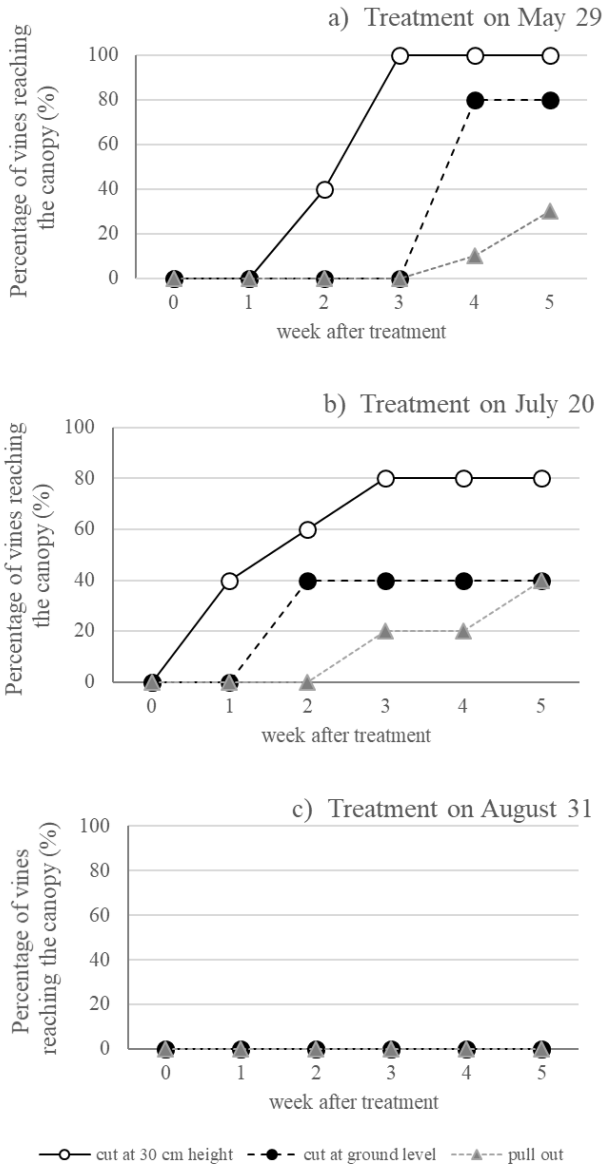

Fig. 2: Percentage of Japanese yam vines reaching the canopy of tea trees after weeding using three different methods during three weeding seasons: on May 29 (a), July 20 (b), and August 31 (c).

in July tended to promote faster vine regeneration, with higher percentages of vines reaching the canopy of tea trees in the first and second weeks after treatment, compared to these treatments in May. However, the final percentage of vines reaching the canopy was lower with treatments in July than with treatments in May.

Currently, tea farmers control Japanese yams by pulling them out individually by hand.

The Japanese yam has a node between the tuber and the base of the vine, and the vine can be pulled out at this node if the base of the vine is held firmly and pulled out. However, in practice, the vines often break off in the middle when attempting to pull them out. Generally, the second harvest of tea is obtained during June–July. This study indicated that when vines were cut during this season, the vines quickly regenerated to the picking surface in just one week. Therefore, it is important to conduct weeding operations just before harvest time.

Interestingly, vines did not reach the canopy of tea trees in all treatments, including cutting treatment and pulling treatments, performed at the end of August (Fig. 2 c). When the vines were cut at 30 cm height, all vines left after cutting died within two weeks, and no side branches or new vines were observed. When the vines were cut at the ground level, although vine regeneration was observed in two of the five plants, vines did not reach the canopy of tea trees. These results suggest that cutting is effective for controlling Japanese yam at the end of August, even though the vines are not completely removed. Notably, cutting at 30 cm height did not result in vine regrowth, and it is possible that cutting at a higher height may be effective for Japanese yam control at this time of year.

Conclusion

When vines of Japanese yam were cut in May or July, vines regrew and reached the canopy of tea trees in 2–4 weeks. Even when the Japanese yam vines were pulled out completely, approximately 40 % of the vines reached the canopy of tea trees in one month. These results suggest that it is difficult to control Japanese yam by only removing vines. Furthermore, although the old tubers were not completely eliminated before new tubers were produced, in July, the old tubers began to disappear, and the new tubers were still small. Therefore, it is expected that repeated vine removal beginning in July will help to wear out the tubers.

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