Effects of Different Levels of Nitrogen Fertilizer Application Through Drip Fertigation on Sweet Corn Yield in Japan

Masanori Takeshita*, Hiromi Masumitsu**, Hajime Goto**, Masaru Tomatsuri**
Kazuhiko Nakaniishi***, Takashi Minohara****, Toshiyuki Maeyama*****, Takehiro Takahashi****
Tetsuya Hibi*****, Yuki Kaminura** and Haruka Yamanaka**

* Takushoku University, Faculty of International Studies, **SUN HOPE, Inc.
*** Nakanishi Farm, Takushoku University, **** Graduate School of Engineering
***** Takushoku University, Faculty of Foreign Languages

Japan ranks 14th on the list of total sweet corn production in the world; however, the ranking decreases to 24th in terms of yield, which represents the amount of production per hectare. This low production efficiency might be due to the conventional Japanese cultivation method; therefore, we applied drip fertigation systems in open fields to increase the yield of sweet corn. Previous studies have shown that the yield of sweet corn can be increased through drip fertigation and that the key factor is nitrogen; however, information about how sweet corn reacts when receiving excessive nitrogen is limited. Therefore, the purpose of this study was to compare the performance of sweet corn using various levels of nitrogen fertilizer with drip fertigation and determine the optimum amount of nitrogen required to produce the maximum crop yield. Six different nitrogen application levels and three different fertigation frequencies were set: (i) 1.5 kg ha⁻¹ day⁻¹, fertigation four times per day (N1); (ii) 15 kg ha⁻¹ day⁻¹, fertigation four times per day (N2); (iii) 30 kg ha⁻¹ day⁻¹, fertigation four times per day (N3); (iv) 1.5 kg ha⁻¹ day⁻¹, fertigation once per day (N1-a); (v) 1.5 kg ha⁻¹ day⁻¹, fertigation once per three days (N1-b); (vi) no drip irrigation (rainfed), and 130 kg ha⁻¹ with local practices using granule fertilizers (Control). The results showed that the yield of sweet corn can be increased 2 to 2.5 times higher than that of conventional rain-fed cultivation practices if plenty of nitrogen fertilizer is applied through drip fertigation. The results also indicated that the yield reached a plateau between N2 and N3, so the N3 level of fertilization would cause more harm than good, especially for the environment. The frequency of irrigation was found to be an important factor for yield, especially during the dry season, and crops should be irrigated daily.

**Key Words**: drip irrigation, drip fertigation, nitrogen fertilizer, sweet corn, yield
1. Introduction

Sweet corn (Zea mays var. rugosa) is a maize variety with high sugar content. Unlike field corn varieties, which are harvested when the kernels are dry and fully matured (dent stage), sweet corn is picked when immature (milk stage) and eaten as a vegetable, rather than as a grain. In terms of total sweet corn production in the world, Japan ranks 14th (FAOSTAT 2020); however, the ranking decreases to 24th when calculations are made based on yield, which represents the amount of production per hectare. This indicates that the production efficiency of sweet corn in Japan is not high. This low production efficiency might be due to the conventional Japanese cultivation method. In Japan, farmers tend to eliminate the second and third ears to concentrate nutrients into only the first ear. This custom, however, not only requires great care, but also decreases yield. For these reasons, we left the second and third ears intact on a stalk in our previous experiment and tried to increase yield using drip fertigation systems (Takeshita et al. 2019).

Drip fertigation, a combination of “drip irrigation” and “fertilization,” involves application of liquid fertilizer via irrigation water. One of the advantages of drip fertigation is its ability to “spoon feed” crop nutrients on an as-needed basis (Bucks and Davis 1986) and precisely delivers water and nutrients to the crop root zone (Sorensen and Lamb 2009), thereby decreasing the potential for environmental contamination. Previous research has shown that drip fertigation systems can be installed with low initial investment and labor and increase crop yield of a variety of crops (Sorensen and Lamb 2008).

Although drip fertigation is commonly used in greenhouses in Japan, there have been few reports on its use in open fields. Most of the studies on drip fertigation in open fields have involved woody species like tea (Shirai et al. 2006, Shirai et al. 2010) and citrus (Morinaga 2010). The literature on drip fertigation of vegetables in open fields is limited to those on bell pepper (Takeshita et al. 2018, Urushibara et al. 2013), lettuce (Ueta et al. 2009), and yam (Toyama et al. 1987). Almost all these studies, however, have focused on decreasing nitrogen fertilizer to protect the environment, and not on increasing crop yield. Therefore, whether drip fertigation in open fields can increase yield is still an open question, especially for sweet corn, which remains poorly studied in Japan.

The most common reason drip fertigation has not been used in open fields in Japan seems to be that there is enough rainfall to grow crops throughout Japan. Most farmers apparently feel that they do not need irrigation in open fields. Research overseas, however, has suggested that even in regions with enough seasonal rainfall, irrigated yields can surpass rainfed yields (Grassini et al. 2009). Our previous research has also shown that drip fertigation can increase the yield of sweet corn in open fields and succeeded in producing multiple ears per stalk up to a maximum of four ears (Takeshita et al. 2019).

The key element inducing an increase in yield is nitrogen, which is especially important in sweet corn production, not only for plant growth but also for the production of amino acids that influence flavor and nutrition (Alcantara 2015). However, the relationship between nitrogen application and the resultant effect on the yield of sweet corn is not fully understood, especially when excessive nitrogen is applied through drip fertigation. Therefore, the purpose of this study was to compare the performance of sweet corn using various levels of nitrogen fertilizer applied via drip fertigation and to determine the optimum amount of nitrogen required to provide the maximum yield.

2. Materials and Methods

The study was conducted between 2018 and 2019 at the University of Takushoku experimental field, Hachioji Tokyo (35° 37′ N, 139° 16′ E, elevation 225 m above sea level) on clay loam soil (Andosol). Hybrid sweet corn (Zea mays var. rugosa) cultivar ‘Canberra 90’ and ‘Megumi-star’ were planted in 2018 and 2019, respectively. The experiment was arranged in a completely randomized design and consisted of six treatments: N1, N2, N3, N1-a, N1-b, and C, each with four replicates. Surface drip fertigation systems were used for irrigation and fertilization to impose
different nitrogen levels and fertigation frequency. The amount of applied Nitrogen was (i) 1.5 kg ha\(^{-1}\) day\(^{-1}\), fertigation four times per day (N1); (ii) 15 kg ha\(^{-1}\) day\(^{-1}\), fertigation four times per day (N2); (iii) 30 kg ha\(^{-1}\) day\(^{-1}\), fertigation four times per day (N3); (iv) 1.5 kg ha\(^{-1}\) day\(^{-1}\), fertigation once per day (N1-a); (v) 1.5 kg ha\(^{-1}\) day\(^{-1}\), fertigation once per three days (N1-b); (vi) no drip irrigation (rainfed), 130 kg ha\(^{-1}\) with local practices using granule fertilizers (Control).

The final amounts of N application were different due to the cultivation period of each cultivar: (i) 136.5 kg ha\(^{-1}\) (2018), 141 kg ha\(^{-1}\) (2019) at N1; (ii) 1,365 kg ha\(^{-1}\) (2018), 1,410 kg ha\(^{-1}\) (2019) at N2; (iii) 2,730 kg ha\(^{-1}\) (2018), 2,820 kg ha\(^{-1}\) (2019) at N3; (iv) 136.5 kg ha\(^{-1}\) (2018), 141 kg ha\(^{-1}\) (2019) at N1-a; (v) 136.5 kg ha\(^{-1}\) (2018), 141 kg ha\(^{-1}\) (2019) at N1-b; (vi) 130 kg ha\(^{-1}\) at C. The rationale for adopting different nitrogen application settings was to make nitrogen levels of N1 and C equal to the standard quantity in Tokyo recommended by the ministry of agriculture, forestry and fisheries of Japan which is 130 kg ha\(^{-1}\). Although the amounts of nitrogen in N2 and N3 were high enough to pollute the environment, the aim of this experiment was to demonstrate how much yield could be increased by increasing nitrogen fertigation.

Corn was sown on April 20\(^{th}\) and April 19\(^{th}\) in 2018 and 2019, respectively, and harvested on July 19\(^{th}\) and July 21\(^{st}\) in 2018 and 2019, respectively. The row spacing was 1 m from the center of one row to the center of an adjacent row, and the plant spacing was 0.5 m. Each plot was 0.5 m wide by 4.5 m long. Hard plastic boards, 1 cm thick, 70 cm deep, were embedded into the soil between each row to prevent corn plant roots from intruding into nearby plots. Drip irrigation laterals were placed on the soil surface under polyethylene black mulch in each plot. Drip fertigation was applied from sowing to harvest in all plots except the control (C) plot. Water (3 mm) was automatically applied every day in N1, N2, N3, N1-a, and N1-b regardless of rainfall. Water (9 mm) was applied for three days in N1-b, and no water was irrigated in C.

The fertilizer used for drip fertigation was “OAT Agrio No.1 for fertigation” (N: P\(_2\)O\(_5\): K\(_2\)O= 15: 8: 17) in N1, N2, N3, N1-a, and N1-b. The general granule synthesized fertilizer (N: P\(_2\)O\(_5\): K\(_2\)O= 8: 8: 8) was used in C. No organic compost was added to the field before this experiment and the previous crop grown was pumpkin. Pesticides were not applied in order to protect honey bees kept in the experimental field; therefore, disease and insect damage were not considered in the process of judging marketable fruits.

Soil samples were taken for chemical analysis three times during the study: immediately after planting; in the middle of cultivation; and immediately after harvest. A soil moisture sensor EC-5 (METER Groups, Inc. USA) was used to measure soil water content.

Precipitation data was obtained from the Japan Meteorological Agency Tokyo Hachioji station. Evapotranspiration was estimated based on the FAO Penman-Monteith equation using the reference evapotranspiration (\(E_{\text{To}}\)) and crop evapotranspiration under standard conditions (\(E_{\text{Tc}}\)). Data from MeteoCrop DB of the National Institute for Agro-Environmental Sciences (https://metecrop.dc.affrc.go.jp/real/top.php) were used to obtain the \(E_{\text{To}}\) and the \(E_{\text{Tc}}\). Statistical analysis was conducted using SPSS statistical software (IBM, ver. 25).

### 3. Results and discussion

#### Amount of water applied, crop evapotranspiration, and soil properties

During the crop growing seasons, the amount of water applied through drip irrigation for N1, N2, N3, N1-a, and N1-b was 500 and 550 mm in 2018 and 2019, respectively. The calculated accumulated evapotranspiration through the cultivation period was 500 mm and 450 mm in 2018 and 2019, respectively. Daily accumulated rainfall, evapotranspiration, and irrigated water are plotted in Fig. 1. The lines of accumulated rainfall plus irrigation surpassed the lines of accumulated evapotranspiration both in 2018 and 2019. This means that irrigated plots such as N1, N2, N3, N1-a, and N1-b had enough water throughout the cultivation period. The lines of accumulated rainfall, however, were lower than those of the accumulated evapotranspiration at the end of the experiment in
This indicated that plot C, which depended only on rainfall, faced a water shortage in 2018. According to the Japan Meteorological Agency, the amount of rainfall at the experimental site from April to July 2018 was 438.5 mm, which was 25% lower than the usual normal value of 583.6 mm during that period. This was confirmed by the soil water content data (Fig. 2). The graph illustrates that the water...
content of irrigated plots (N1, N2, N3, N1-a, and N1-b) remained high (above 15%) in 2018, whereas plot C shows a water shortage after days 160. Figure 2 also indicates that plot C experienced water shortage between day of year (DOY) 110 and 145 in 2019 from the emergence stage to the tasseling stage. This shortage can be observed in Figure 1, where the line of rainfall is lower than the line of evapotranspiration between DOY 130 and 140 in 2019. It is also noteworthy that the amount of solar radiation was very small in July 2019. The normal value of solar radiation in July was 141.6 hours per month, whereas it was only 73.3 hours per month in 2019. These combined factors seemed to have harmful effects on corn growth.

The results of the soil chemical analyses are summarized in Table 1. Before conducting the experiment, in both 2018 and 2019 soil chemical analyses were performed. The results of these analyses are summarized in Table 1.
properties were not poor except for the lack of available phosphorus due to the nature of the soil, viz., volcanic ash (Andosol). During and at the end of the experiment, both in 2018 and 2019, nitrate levels increased dramatically at N2 and N3 to levels considered harmful to the environment. EC and acidity (pH) also increased at N2 and N3 because of the high nitrate levels.

4. Yield and plant growth

The yields of N2 and N3 were significantly greater than those of the other plots in both 2018 and 2019 (Table 2). The total marketable ear yields were almost the same between N2 and N3 in both 2018 and 2019, and the maximum yields were 2.1 and 2.4 times higher than the minimum yields of C in 2018 and 2019, respectively. Regarding the yield of ears larger than M size, which is over 300 g, the difference between the maximum yields at N2 and N3 and the minimum yields at C became greater by 3.6 and 2.3 times in 2018 and 2019, respectively. The dry matter weight showed the same tendency that at N2 and N3 were maximum and were 2.2 and 2.4 times greater than the smallest at C in 2018 and 2019, respectively.

There was a significant difference in the number of harvested ears (Table 3). The numbers of ears bigger than M size at N2 and N3 were the highest, at 1.8 and 1.6 ears per stalk, while the numbers at C were the lowest, at 0.7 and 0.8 ears per stalk in 2018 and 2019, respectively. The plant height at C was significantly lower than that at others in 2018, and the heights at C and N1-b were significantly lower than that at others in 2019. The plant diameters revealed a similar tendency. The effect of drip fertigation was clearly observed on the number of tillers; every corn in N3 had two or more tillers in addition to the main stalk. There was no significant difference in the

| treatment | Marketable Ear yield | Dry matter | Plant height | Plant diameter | Plant death rate |
|-----------|----------------------|------------|--------------|---------------|-----------------|
|           | t/ha                 | t/ha       | t/ha         | cm            | cm              | %               |
| 2018C     | 8.0 a                | 4.1 a      | 1.8 a        | 140 a         | 2.2 a           | 28.1            |
| 2018N1    | 11.8 ab              | 9.0 ab     | 2.7 ab       | 172 bc        | 2.7 ab          | 7.1             |
| 2018N2    | 16.5 b               | 14.7 b     | 3.9 b        | 189 c         | 3.0 b           | 0.0             |
| 2018N3    | 16.0 b               | 13.9 b     | 3.9 b        | 176 bc        | 2.8 ab          | 7.1             |
| 2018N1-a  | 13.1 ab              | 10.1 ab    | 3.0 ab       | 176 bc        | 2.7 ab          | 3.6             |
| 2018N1-b  | 9.0 a                | 5.0 a      | 2.2 a        | 160 ab        | 2.5 ab          | 9.0             |
| 2019C     | 8.0 a                | 6.0 a      | 1.8 a        | 161 a         | 2.8 a           | 7.1             |
| 2019N1    | 12.8 abc             | 9.6 ab     | 2.9 abc      | 174 abc       | 3.0 a           | 16.1            |
| 2019N2    | 17.9 bc              | 13.6 b     | 3.9 bc       | 186 bc        | 3.5 b           | 3.1             |
| 2019N3    | 19.4 c               | 13.5 b     | 4.4 c        | 187 c         | 3.5 b           | 11.8            |
| 2019N1-a  | 10.3 ab              | 8.1 ab     | 2.3 ab       | 171 ab        | 3.2 ab          | 3.6             |
| 2019N1-b  | 10.4 ab              | 8.0 ab     | 2.6 ab       | 168 a         | 2.7 a           | 6.7             |

Analysis of variance F-test probability

| treatment | 2018 | 2019 |
|-----------|------|------|
| treatment | 0.00 | 0.00 |
|          | 0.00 | 0.23 |

* Different letters indicate significant differences at p < 0.05 using Duncan’s multiple range test. Marketable ears are divided into 4 sizes; S size is less than 300 g, M size is between 300 g and 400 g, L size is between 400 g and 450 g, and 2 L size is more than 450 g. Disease and insect damage were excluded from the criterion for the marketable ear.
Our experimental results indicate that the yield of sweet corn can be increased 2 to 2.5 times higher than that of conventional rain-fed cultivation practices if plenty of nitrogen fertilizer is applied through drip fertigation systems. A stable 2 ears harvest per stalk would be possible when the amount of nitrogen fertilizer as that applied in N2 (1,400 kg ha\(^{-1}\)) is used. Although the amount of N fertilizer applied at N3 was twofold greater than that applied at N2, there was no significant difference in sweet corn yield between them. This indicates that N2 already reached a yield plateau, and that the N3 level of fertilization would not lead to increased yield but could harm the environment.

Although there was no significant difference in yield between N1 and C, every average yield of N1 was greater than that of C. It is possible that if we had more replicates, the results could have shown a significant difference between C and N1. Given the fact that the amount of applied N fertilizer was

| treatment | Number of marketable Ears | Number of tillers | sugar content | nitrate level |
|-----------|---------------------------|-------------------|---------------|--------------|
|           | total ears/stalk           | bigger than L size ears/stalk | bigger than M size ears/stalk | tillers/stalk | oBX ppm |
| 2018C     | 1.9                        | 0.2a               | 0.7a          | 1.0ab        | 18.3  | 92.5 |
| 2018N1    | 1.8                        | 0.5ab              | 1.2ab         | 1.2ab        | 13.6  | 65.5 |
| 2018N2    | 2.2                        | 1.2c               | 1.8b          | 1.7ab        | 15.1  | 75.0 |
| 2018N3    | 2.1                        | 1.1b               | 1.7b          | 2.1b         | 14.2  | 71.0 |
| 2018N1-a  | 2.0                        | 0.3a               | 1.3ab         | 1.6ab        | 17.2  | 79.0 |
| 2018N1-b  | 1.7                        | 0.2a               | 0.7a          | 0.7a         | 15.1  | 75.0 |
| 2019C     | 1.2a                       | 0.4a               | 0.8a          | 0.8a         | 10.3a | 73.3 |
| 2019N1    | 1.9ab                      | 0.7a               | 1.1abc        | 1.4a         | 14.0ab | 66.0 |
| 2019N2    | 2.8b                       | 1.1a               | 1.6c          | 2.5b         | 12.5ab | 62.0 |
| 2019N3    | 3.2c                       | 1.0a               | 1.5b          | 2.6b         | 12.8ab | 93.0 |
| 2019N1-a  | 1.7ab                      | 0.5a               | 1.0ab         | 1.4a         | 14.8b  | 68.3 |
| 2019N1-b  | 1.7ab                      | 0.5a               | 1.0ab         | 1.4a         | 14.3ab | 72.0 |

Analysis of variance F-test probability

| treatment | 2018 | 2019 |
|-----------|------|------|
|          | 0.49 | 0.00 |
|          | 0.00 | 0.00 |
|          | 0.00 | 0.00 |

* Different letters indicate significant differences at \(p < 0.05\) using Duncan’s multiple range test. Marketable ears are divided into 4 sizes; S size is less than 300 g, M size is between 300 g and 400 g, L size is between 400 g and 450 g, and 2L size is more than 450 g. Disease and insect damage were excluded from the criterion for the marketable ear.

plant death rate and nitrate levels of fruits. A slightly significant difference was found in sugar content of fruits only in 2019 between C and N1-a, yet there did not seem to be any meaningful trend.

5. Effects of nitrogen and irrigation frequency

The main purpose of this experiment was to confirm how much we can increase the yield of corn when excessive nitrogen fertilizer was applied through drip fertigation. Our previous studies have already proven that we can increase yield through drip fertigation (Takeshita et al. 2019), and several studies by other authors have supported this (Hatlitligil et al. 1984, Williams et al. 2010). Information detailing the effect of nitrogen fertilization on yields is well documented (Hatlitligil 1984). However, information about how sweet corns react when they receive excessive nitrogen fertilizer is limited.

Our experimental results indicate that the yield of sweet corn can be increased 2 to 2.5 times higher than that of conventional rain-fed cultivation practices if plenty of nitrogen fertilizer is applied through drip fertigation systems. A stable 2 ears harvest per stalk would be possible when the amount of nitrogen fertilizer as that applied in N2 (1,400 kg ha\(^{-1}\)) is used. Although the amount of N fertilizer applied at N3 was twofold greater than that applied at N2, there was no significant difference in sweet corn yield between them. This indicates that N2 already reached a yield plateau, and that the N3 level of fertilization would not lead to increased yield but could harm the environment.

Although there was no significant difference in yield between N1 and C, every average yield of N1 was greater than that of C. It is possible that if we had more replicates, the results could have shown a significant difference between C and N1. Given the fact that the amount of applied N fertilizer was
almost the same between N1 and C, it may be suggested that drip fertigation is more productive than conventional cultivation practices with granule fertilizers.

The effect of irrigation frequency on yield can be confirmed by comparing N1, N1-a, and N1-b. Studies concerning high-frequency irrigation in open fields are limited in Japan. As far as we know, there are no reported studies about this issue on sweet corn in open fields. In contrast, there are many reports regarding irrigation frequency in foreign countries; however, these reports have produced contradictory results. While several studies associate enhanced yield to more frequent water applications (Kang et al. 2004, Hunsaker et al. 1998), others found no differences (Assouline 2002, Xu et al. 2004). Our experimental design set three levels of irrigation frequency: N1 had irrigation four times per day, N1-a had irrigation once per day, and N1-b had irrigation once per three days. The results showed that there was no significant difference in total yield between them in 2019, while in 2018, the total and > M size yields of N1-b were particularly small. Only the yields of N1-b and C were significantly smaller than those of N2 and N3 in 2018. One reason for this difference seems to be the dry weather of 2018. In other words, if there is enough rainfall, as was the case in 2019, the irrigation frequency makes no difference. However, if there is dry weather, as was the case in 2018, irrigation once per three days is not enough for the crop to grow optimally.

6. Installation and cost of the system

Additionally, it is worth mentioning that the installation of a drip fertigation system is easy and economical. The simplest form of a drip fertigation system, whose irrigation timing is scheduled by a timer, costs approximately 500,000 Japanese yen for materials and 120,000 yen for labor charges per 10a. It takes only a day to install the drip fertigation system at a farm, including fertilizer injectors, disc filters, magnetic valves, fertilizer tanks, and drip tubes. Once farmers acquire good knowledge regarding the system, they can change the layout of the tubes themselves every season according to the needs of each crop. The drip fertigation system is applicable to all crops, such as vegetables, fruits, flowers, and grains. A variety of liquid fertilizers for this system are sold in Japan, and even organic liquid fertilizers are available. The running cost is negligible. Farmers can save water and fertilizer to a large extent because the drip fertigation system uses the minimum required amount and applies these only around the root zone. This system also saves labor. Considering corn cultivation, farmers do not need to do anything after installing this system except pest management. They do not have to worry about drought in summer anymore, and the yield is expected to double. The irrigation and fertigation efficiency will be improved further if farmers adopt more sophisticated systems such as sensor networks, satellite images, and cloud systems. Then, farmers can view all information using a mobile phone and operate the system from anywhere.

References

Alcantara C G. (2015): Response of Sweet Corn (Zea mays var. rugosa) to Drip Fertigation in Varying Levels of Nitrogen. Mindanao Journal of Science and Technology. 13: 32-50.

Assouline S, Cohen S, Meerbach D, Harodi T and Rosner M. (2002): Microdrip irrigation of field crops: effect on yield, water uptake, and drainage in sweet corn. Soil Sci. Soc. Am. J. 66: 228-235.

Bucks D A, and Davis S. (1986): Trickle Irrigation for Crop Production. Chapter 1: Historical development. F. S. Nakayama and D. A. Bucks, eds. Amsterdam, The Netherlands: Elsevier.

FAOSTAT. (2020): Food and Agriculture Organization of the United Nations. http://www.fao.org/faostat/en/#home

Grassini P., Yang H. and Cassman K.G. (2009): Limits to maize productivity in Western corn-belt: a simulation analysis for fully irrigated and rainfed conditions. Agric. Forest Meteorol. 149: 1254-65.

Hatlitligil M B, Olson R A and Compton W A. (1984): Yield, water use, and nutrient uptake of corn
hybrids under varied irrigation and nitrogen regimes. Fertilizer Research. 5: 321-333

Hunsaker D J, Clemmens A J and Fangmeier D D. (1998): Cotton response to high frequency surface irrigation. Agri. Water Manage. 37: 55-74.

Kang Y, Wang F, Liu H and Yuan B. (2004): Potato evapotranspiration and yield under different drip irrigation regimes. Irrigation Sci. 23: 133-143.

Morinaga K, et al. (2010): Development of Drip Irrigation and Liquid Fertigation System with Plastic Mulching and Its Extension for Citrus Fruit Production. Hort. Res. Japan. 9(2): 129-135.

Shirai K., Tsuji H and Kinoshita T. (2006): The Water Saving Irrigation by the Autoirrigation with the tensiometer in the Drip Fertigation of Tencha tea garden. Res. Bull. Aichi Agric. Res. Ctr. 38: 147-153.

Shirai K, Tsuji M, Hiei K, Tsuji H and Kinoshita T. (2010): The Possibility of Continuous Cultivation of Liquid Fertilizer Application on Tencha Tea Field. Res. Bull. Aichi Agric. Res. Ctr. 42: 163-170.

Sorensen R B, and Lamb M C. (2008): Corn and cotton yield with two surface drip lateral spacings. Online. Crop Management DOI: 10.1094/CM-2008-0118-01-RS.

Sorensen R B, and Lamb M C. (2009): Peanut yield, market grade, and economics with two surface drip lateral spacings. Peanut Sci. 36: 85-91.

Takeshita M, et al. 2018. Influence of Drip Irrigation and Drip Fertigation on the Yield of Bell Peppers in Open Fields. Japanese Journal of Farm Work Research. 53(4): 183-194.

Takeshita M, et al. (2019): Effects of Drip Irrigation and Fertigation on Yield and Production of Multiple Ears of Sweet Corn in Japan. Japanese Journal of Farm Work Research. 54(3): 151-161.

Toyama M et al. (1987): Studies on Chinese Yam (Discocrea opposite) Cultivation by Drip Irrigation in Sandy Field (II) Effects of Mulching and Amount of Irrigation. Bull. Sand Dune Res. Inst., Tottori Univ. 26: 73-81.

Ueta T et al. (2009): Effects of drip fertigation on yield and quality of leaf vegetables, and on efficiency of nitrogen fertilization in outdoor plant culture. Japanese Society of Soil Science and Plant Nutrition. 80(5): 477-486.

Urushibara S, et al. (2013): Effects of drip irrigation and phosphate fertilizer reduction on yield in green pepper. Tohoku Agric. Res. 66: 145-146.

Williams J D, Kitchen N R, Scharf P C and Stevens W E. (2010): Within-field nitrogen response in corn related to aerial photograph color. Precision Agric. 11: 291-305.

Xu G, Levkovitch Y, Soriano S, Wallach R and Silber A. (2004): Integrated effect of irrigation frequency and phosphorus level on lettuce: P uptake, root growth and yield. Plant Soil. 263: 297-309.

要旨

スイートコーンの総生産量に関して日本は世界14位となっているが、1 ha 収量になると24 位まで落ちる。その生産効率をあげるために、以前の研究において、ドリップ・ファーティゲイションを露地栽培に導入した。その結果、ドリップ・ファーティゲイションによりスイートコーンを増収できることができた。Nを増やしていったとき、どこまで増収可能なのかは未知数であった。そこで様々なNレベルおよび灌水頻度を設定することにより、増収に最適な窒素量、灌水頻度を求めることを本研究の目的とした。試験区はN1：窒素 1.5 kg ha⁻¹ day⁻¹、灌水 4 回 day⁻¹：N2：窒素 15 kg ha⁻¹ day⁻¹、灌水 4 回 day⁻¹：N3：窒素 30 kg ha⁻¹ day⁻¹、灌水 1 日 1 回：N1-a：窒素 1.5 kg ha⁻¹ day⁻¹、灌水 1 回 day⁻¹：N1-b：窒素 1.5 kg ha⁻¹ day⁻¹、3日に1回灌水：C：灌水なし（降雨のみ）固定化成窒素肥料 130 kg ha⁻¹ とした。結果、ドリップ・ファーティゲイションにより 2-2.5 倍に増収が可能となったが、収量の頭打ちも見られ、N3 レベルの多施肥は弊害の方が大きいことがわかった。灌水頻度は、2018年のように乾燥した年には強く収量に影響しており、毎日の灌水が最適と思われた。

キーワード

収量、スイートコーン、点滴灌漑、点滴灌漑同時施肥、ドリップ・ファーティゲイション