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著者	SULAIMAN Hamid, SASAKI Osamu
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Influence of Planting Density on the Root Growth and Yield of Sweet Potato (*Ipomoea batatas* Lam.)

Hamid SULAIMAN and Osamu SASAKI
(*Laboratory of Crop Science*)
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Introduction

Planting density is one of the major factors influencing tuber yield of sweet potato[1]. Many studies concerning this relationship have been reported[1, 9, 10]. This is quite natural, since increasing planting density may cause competition among plants not only for light but also for water and nutrients in potato plant[2]. The roots of sweet potato are characterized by a remarkably the deep root system and the distribution of rootlets equally covering a wide rang e[14]. However, concerning the influence of planting density on the root growth and yield of sweet potato plant information on root growth was very scarce. Information on roots may be quite necessary to fully understand the influence of planting density on plant growth and tuber yield.

One of the aims of this study is to clarify the influence of planting density on root growth and its relationship to leaf and tuberous root growth in sweet potato. Two main crop cultivars considered to be different in their adaptabilities for yields were used.

Materials and Methods

The experiment was conducted on the experimental field of the Faculty of Agriculture, Kagoshima University in 1999. Two sweet potatoes (*Ipomoea batatas* Lam.) in term growth-habit, cv. Koganesengan (*early thickening type*) cv. Norin No. 1 (*late thickening type*) were used in this experiment. Those were planted with a row width of 1.0 meter. The hill distance in the rows was changed, depending on the planting densities; 35 cm in the high densities plot (2.85 hills per m^2) and 70 cm in the low densities plot (1.42 hills per m^2) respectively. The main plot for the density treatment consisted of 24 rows and 5 hills in rows, being divided into sub-plots for the two cultivars. The cultivars were planted with one stem cutting per hill. Each cutting was approximately 15 gram in fresh weight, 25 cm in length, having 7 stem nodes. The 3 stem nodes were planted in the soil. The field was ploughed, rotorvated and mulching by polyethylene film had been done before planting. The fertilizer rate used was 60 kg N, 60 kg P, 180 kg K, 800 kg Mg lime and 10,000 kg cow dung per hectare. When necessary, herbicides were sprayed and hand-weeding was done to weed control. Pesticides also were sprayed four times to prevent the leaf damage from insects.

As shown in Fig. 1 the roots sampling was done at 50, 100 and 150 days after planting (DAP). The stems and leaves of each hill were combined in some complicated ways with those of neighboring hill, and then they were separated and cut off at the ground surface. Dead leaves and stems were not collected. Soil monoliths (30 cm in width, 30 cm in length and 20 cm in depth per monolith) were dug from the center of the row for shallow layer sample. For deeper layer sampling, soil monoliths (30 cm in width, 30 cm in length and 25 cm in depth per monolith) were dug in to the soil. The number of sampling in each cultivar was five in the each plot. Immediately after digging, the roots were washed with running water to remove soils and other plant residues. The samples consisting of rootlet (< 2 mm in diameter), medium root (> 2 mm in diameter) and tuberous root (> 1 cm in diameter) were collected. The leaf area was measured with an automatic leaf area meter. In the rootlet, medium root and shoots (leaves and stems) dry weight (DW) was recorded after oven-drying carried out for 48 hours at 80℃. However, tuberous root DW was determined after the tubers were cleaned, sliced and oven dried for 120 hours at 80℃.

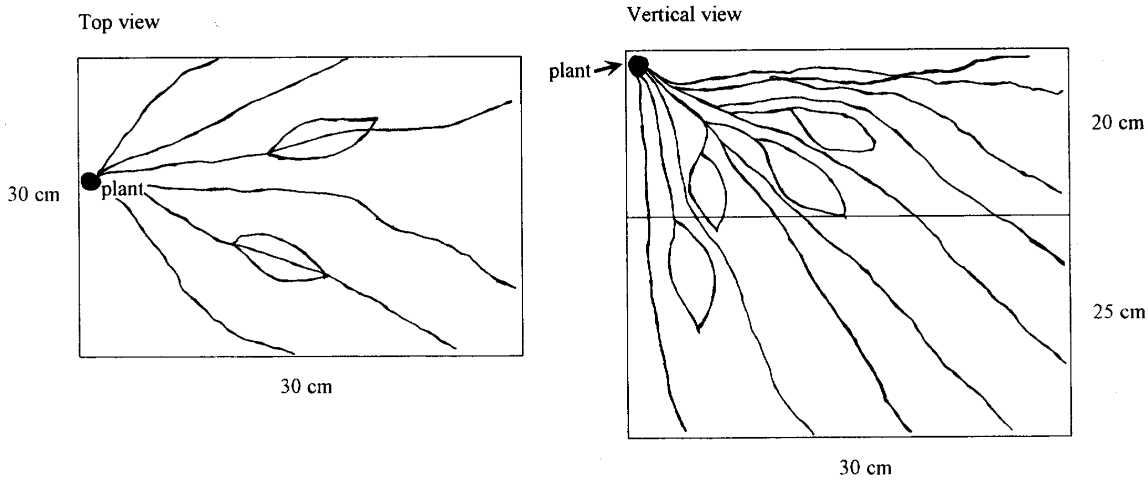


Fig. 1. Division of soil blocks for investigating roots.

Results

Leaf area index (LAI)

Fig. 2 shows the leaf area index (LAI) of the two sweet potato cultivars during the growing season. The LAI for both cultivars increased progressively until the 100 DAP, slightly declining until 150 DAP, the rate of which depending on planting density. Subsequent changes varied among planting densities until the final harvest. The major increasing and differences in LAI occurred from the beginning to 100 DAP for all cultivars grown at the high density. LAI for cv. Norin No. 1 was largest compared to that for cv. Koganesengan.

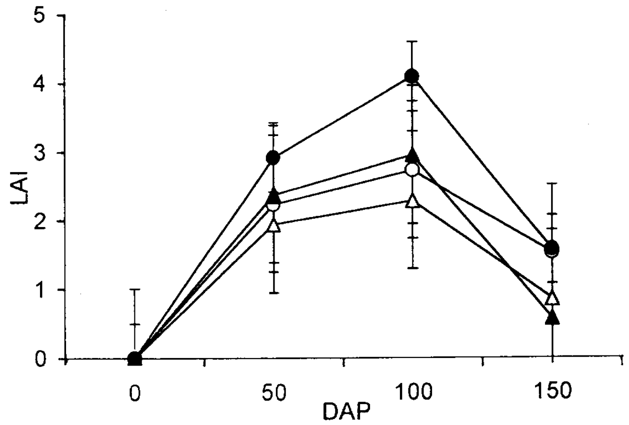
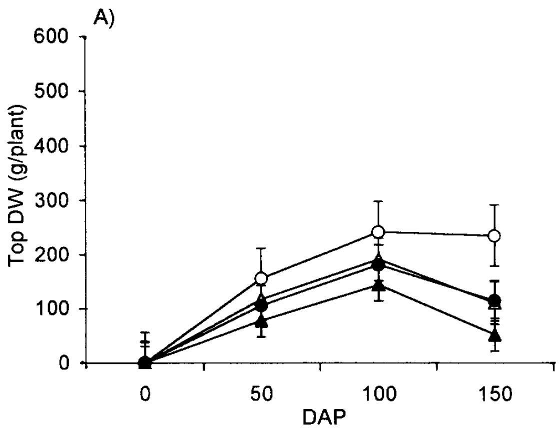


Fig. 2. Changes in leaf area index (LAI) of two sweet potato cultivars and two planting densities during the growing season.
Symbol: ●: 35 cm-Norin No. 1, ▲: 35 cm-Koganesengan, ○: 70 cm-Norin No. 1. and △: 70cm-Koganesengan.
Vertical bar indicates the value of LSD (0.05).

Top dry weight (DW)

Fig. 3 shows that the differences between low and high densities in top-DW per plant and top-DW per m^2 for both cultivars were clear. The top-DW per plant for both cultivars increased from early growth to 100 DAP and slightly declined at 150 DAP. The top-DW per plant was largest in cv. Norin No. 1 under low density. Increasing in the planting density obviously showed some increases at the top-DW per m^2 in both the cultivars. The top-DW per m^2 of both the cultivars increased progressively until 100 DAP and the greatly declined until the 150 DAP. Sweet potato cv. Norin No. 1 showed the largest top-DW per m^2 compared to that of cv. Koganesengan.



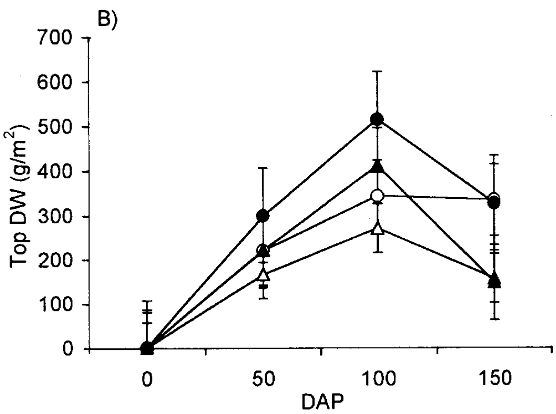


Fig. 3. Changes in top-DW per plant (A) and top-DW per m^2 (B) of two sweet potato cultivars and two planting densities during the growing season.
Note:Symbols are the same as those in Fig. 2.
Vertical bar indicates the value of LSD (0.05).

Tuberous root DW

Sweet potatoes of both the cultivars grown under two planting densities showed some similar trend of tuberous roots-DW per plant and per m^2 from the 50 DAP to the 150 DAP (Fig. 4). The tuberous roots-DW per plant for all the cultivars were higher in those grown under low density at the 150 DAP. No differences in tuberous roots-DW per plant were observed between the two cultivars grown under low density. However, the differences in tuberous roots-DW per plant between the both densities were evident at the late season. The results show that the differences in tuberous roots-DW per plant between the plots were mainly due to the differences in the increasing of tuberous roots-DW per plant at the late season. The tuberous roots-DW per m^2 increased as the season progressed at the rate varying with the planting densities (Fig. 4B). Differences due to the plant spacing increased obviously from 50 to 150 DAP, when the growth of the plants of cv. Norin No. 1 under high density increased relatively in comparison to plant under low density. Sweet potato cv. Koganesengan showed the higher tuberous roots-DW per m^2 compared to that in Norin No. 1 under high density.

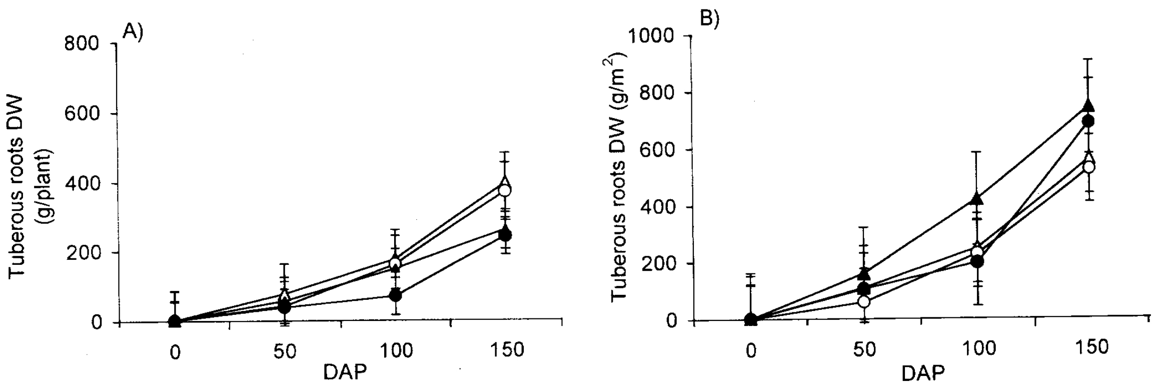


Fig. 4. Changes in tuberous roots-DW per plant (A) and tuberous roots-DW per m^2 (B) of two sweet potato cultivars and two planting densities during the growing season.
Note: Symbols are the same as those in Fig. 2.
Vertical bar indicates the value of LSD (0.05).

Non-tuberous roots DW

The distributions of non-tuberous roots (rootlets and medium roots) per plant at the shallow and deeper layers are shown in Fig. 5. Many of the non-tuberous roots were distributed at the shallow layer (Fig. 5A) rather than at the deeper layer (Fig. 5B). The results showed that the non-tuberous roots-DW per plant in cv. Koganesengan was higher, compared to that in the Norin in both layers. Similar variations were found in the non-tuberous roots-DW per plant in both of the cultivars-distribution at the shallow layer during the growing season (Fig. 5A). The non-tuberous roots-DW per plant increased progressively in both of the cultivars, reaching a peak at 50 DAP. During the later part of the season, the non-tuberous roots-DW per plant in both cultivars showed great declines at all the plant densities. Increases in planting density showed a clear difference in non-tuberous roots-DW per m^2 between the two cultivars distributions at the shallow and deeper layers (Fig. 6). Non-tuberous roots-DW per m^2 of the two cultivars reached maximum at 50 DAP at both the layers, showing a greater decline at all the plant densities at the shallow layer; however, at the deeper layer non-tuberous roots-DW slightly decreased after 50 DAP. Sweet potato cv. Koganesengan showed a higher non-tuberous roots-DW per m^2 than that in cv. Norin No. 1 at both the layers. There was no difference in non-tuberous roots-DW per m^2 between the two cultivars grown under the low density at both layers. Similar trends were found in non-tuberous roots-DW per m^2 and per plant at 45 cm under ground (Fig. 7). The non-tuberous roots-DW per m^2 and per plant increased progressively in both the cultivars under both densities and reached maximum at 50 DAP and slightly declined until 150 DAP. Both of the sweet potato cultivars grown under high density showed a difference in non-tuberous roots-DW per m^2 and per plant at 50 and 100 DAP. Compared to cv. Norin No.1, cv. Shiroyutaka showed the higher non-tuberous roots-DW per m^2 when it was grown under high density.

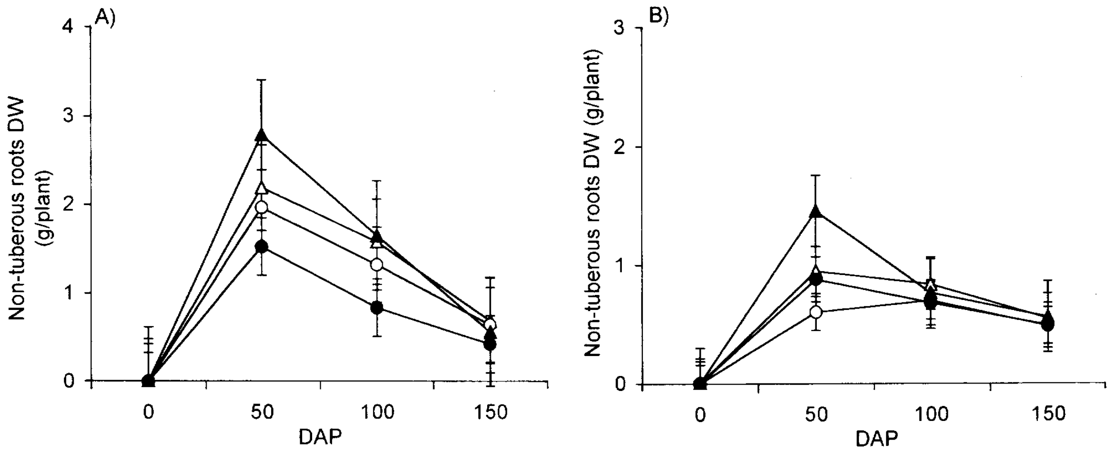


Fig. 5. Changes in non-tuberous roots-DW per plant of two sweet potato cultivars and two planting densities distribution at the shallow layer(A) and deeper layer (B).
Note: Symbols are the same as those in Fig.2.
Vertical bar indicates the value of LSD(0.05).

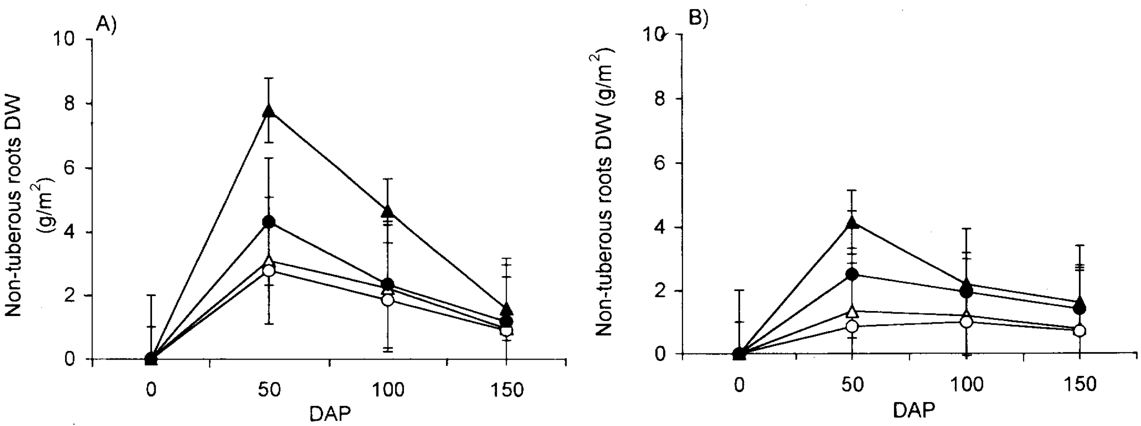


Fig. 6. Changes in non-tuberous roots-DW per m^2 of two sweet potato cultivars and two planting densities distribution at the shallow layer (A) and deeper layer (B).
Note: Symbols are the same as those in Fig. 2.
Vertical bar indicates the value of LSD (0.05).

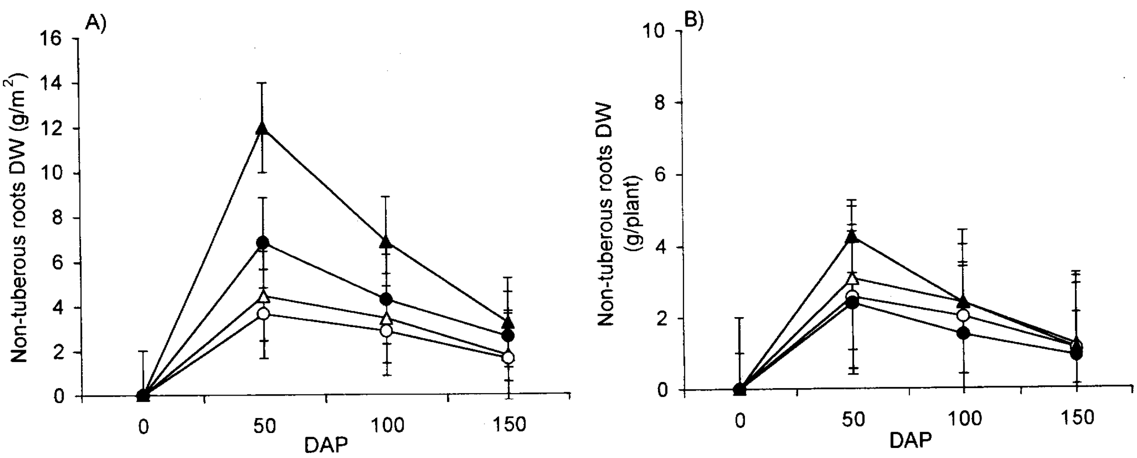


Fig. 7. Changes in non-tuberous roots-DW per m^2 (A) and per plant (B) of two sweet potato cultivars and two planting densities distribution at the 0-45 cm depth.
Note: Symbols are the same as those in Fig. 2.
Vertical bar indicates the value of LSD(0.05).

Discussion

Based on the general descriptions from the above-described studies, the results show that, the LAI, top-DW per m^2 and tuberous roots-DW per m^2 increased with the increasing of the density. Furthermore, increasing of the density showed a clear increase in non-tuberous-roots-DW of all the two cultivars distributed at the shallow and deeper layers. Sweet potato plants cv. Koganesengan and Norin No. 1 grew rapidly under two planting densities. Canopy development, as it was reflected by LAI, increased most rapidly in all the cultivars under both densities from the beginning until 100 DAP, and then showed a greater decline at the late season. Li and Yen[6] reported that, the development showed peaking of LAI at 90 days, only slightly declined at 120 days, and then showed a greater decline until 180 days. Furthermore our findings that the LAI of both cv. Koganesengan and cv. Norin No. 1 showed a greater decline after 100 DAP, earlier than what was reported by Li and Yen[6]. One possible explanation was that, cool day and night temperatures which prevailed during autumn caused the leaf-losses. In the present study, the results showed that the LAI increased with the increasing of the planting density through all the cultivars. LAI per unit plant showed a decreasing trend. This may be attributed to the light interception differences, which occurred in plant canopies under different densities. The LAI of cv. Norin No. 1 was larger than that of cv. Koganesengan. It was due to cultivars characteristic suitable to light application of fertilizer[13].

The non-tuberous roots-DW per m^2 also increased with the increasing of planting density. Especially at 50 DAP when the roots showed the maximum, the respective cultivars of Norin No.1 and Koganesengan showed increasing in top and tuberous roots DW during the growing season. The highest in tuberous roots may be due to growing potential in vegetative growth. The present result was agreed with that of Austin and Aung[3], who reported that tuberous root weight increasing occurred concurrently with the growth of the vegetative tops. It was observed that the maximum vegetative tops weight preceded the maximum tuberous roots development until 100 days, and when the rapid increases in tuberous root weight were taking place, vegetative top weight remained declined. It may be due to the fact that a relative valance between the roots and the leaves is constantly maintained even if their growth changes largely according to the planting density.

Many of the non-tuberous roots for all the two cultivars were distributed at the shallow layer (20 cm under ground) during the growing season. The activity of non-tuberous roots almost had already been lost after 50 DAP, however, Yamashita et.al.[14], reported that, the activity of rootlets had already been lost after 6 months when they were transplanted to the field with different materials and methodology. The results from sampling of the soil hardness fixed with the use of Soil Hardness Tester Yamanaka, showed the soil hardness at the shallow layer was 2 kg/cm^2 and 4.7 kg/cm^2 at the deeper layer. Our observation of soil hardness was due to the soil compaction by tractor cultivation. Our results also agreed with the findings of Meredith et al.,[7] who observed the compaction changes soil in physical properties, which, adversely affects both root and shoot growth of most agronomic crops, especially at the early stages of growth. As a consequence, soil compaction associated with high soil bulk density may be hindered root growth and distribution thus affecting water and nutrient uptake by the plants.

During the growing season there were some changes in the distribution of the roots in the soil at the shallow and deeper layers. When the density increased, non-tuberous roots-DW per plant increased only in cv. Koganesengan at the shallow layer. However, non-tuberous roots-DW per plant increased in both the cultivars with the increasing in the density at the deeper layer. Generally, it may be said that to absorb water in dry soil condition is more necessary to deep roots than to shallow roots. The present results therefore suggest that in dry soil conditions a water shortage in the leaves may become more severe in high densities plot. Confronted with the fact that in the present study the leaves showed no symptoms of water shortage at the late stage, we supposed that it might have been due to plentiful rainfall at that stage of the present year.

There were also some changes in the distribution of the leaves in the canopy. The position of highest leaf area density in the canopy became higher in all the cultivars when planting density increased. Somda and Kays[11] reported that the distribution of leaves on the branches and percentage of missing leaves during the growing season were affected by the planting density. Nakaseko et al.[8] and Isoda et al.[4] reported the same phenomenon. They explained that the larger shading between the leaves increased the leaf-death at the low position in the canopy of the potato plant grown in the high densities plot. In case of the root distribution, it would be unreasonable to explain that some competition between the roots increased the root death in the deep soil layer in high densities plot. Because, the deep roots generally grow at a later stage than that of shallow roots. We supposed that the shallow roots got priority to grow when the root growth per plant was depressed in the high densities plot.

Both cultivars (Norin No.1 and Koganesengan) showed a high tuber yield per area under high planting density. It mainly was resulted from the higher tuberous root-DW at the end of the stage. Although the amounts of fertilizers applied in the present experiments were equal in all the plots, the present soils were rich in nutrients. We considered that a lot of non-tuberous roots per area (m^2) at 45 cm under ground at the high densities plot made it possible to absorb more soil nutrients and to maintain larger leaf area and tuber growth rate at the end of the stage. Iwama[5] had reported in their research in potato plant that the tuber bulking rate increased proportionally with the increasing of the maximum root DW during the growing season.

Based on these observations, we may conclude that the roots of two sweet potato cultivars were tested by a remarkably deep distribution of root system (non-tuberous roots) at the shallow and deeper layers concerning the soil equally covering a wide range of environmental condition. The root system could be a major factor supporting active growth and high productivity even under hard conditions and high plant densities. Moreover, the results obtained provide new information for the determination of the appropriate density of planting in root system of sweet potato plant.

Summary

Influences of planting density on the root growth and the yield of sweet potato (*Ipomoea batatas* Lam.) were studied. Two main crops of sweet potato cultivars Koganesengan and Norin No.1 and the two levels of planting density (35 and 70 cm X 100-cm spacing) were examined. Sampling was done at 50, 100 and 150 days after planting (DAP). The non-tuberous roots including rootlet ($<$ 2 mm in diameter), medium root ($>$ 2 mm in diameter) and tuberous root ($>$ 1 cm in diameter) also were investigated to a depth of 45 cm under ground. LAI increased progressively from early stage until the 100 DAP in both the cultivars at the higher densities and then greatly declined until the 150 DAP. Our observation fixed that, cool day and night temperatures, which prevailed during autumn caused leaf losses. The differences between low and high densities in top-DW per area (m^2) in both the cultivars were evident. Increasing of the plant densities obviously shows that the top-DW and tuberous roots-DW per m^2 in both cultivars increased. Many of the non-tuberous roots were distributed at the shallow layer (0-20 cm) and the loss of activity of roots which occurred after 50 DAP caused the soil hardness by soil compaction. Furthermore, most of the tuberous roots were formed within a mound of each ridge at the shallow layer. Based on these observations, we may conclude that the roots of two sweet potato cultivars were tested by a remarkably deep distribution of root system (non-tuberous roots) at the shallow and deeper layers concerning the soil equally covering a wide range of environmental condition.

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References

1) Anderson, W. S., Cockran, H. L., Edmond, J.B., Wright, R. E., and Boswell, V. R.: Regional studies of time planting and hills spacing of sweet potatoes. U. S. Dept. Agric., Circ., 725 (1945)
2) Allen, E. J.: Plant density. In Harris, P.M. ed., The Potato Crop. Chapman and Hall, London. 278-326 (1978)
3) Austin, M.E., Aung, L.H., Graves, B.: Some observations the growth and development of sweet potato (*Ipomoea batatas*) *J. Hortic. Sci.*, **45**, 257-264 (1970)

4) Isoda, A., Nakaseko, K., and Gotoh, K.: Effects of planting density on growth of the andigena strain (*S. tuberosum ssp. andigena*). *Jpn. J. Crop. Sci.*, **54**, 311-317 (1985) (in Japanese with English summary)
5) Iwama, K.: Difference in root growth of potato plants among years and cropping seasons. *Jpn. J. Crop. Sci.*, **57**, 346-354 (1988)
6) Li, L. and Yen, F.: The effect of cultural practices on dry matter production and partition in sweet potato (*Ipomoea batatas*) cultivars. *J. Agr. Assn. Chem.*, **141**, 47-61 (1988)
7) Meredith, H. L. and Patrick, W. H. Jr.: Effects of soil compaction on sub soil root penetration and physical properties of three soils in Louisiana. *Agron. J.*, **53**, 163-167 (1961)
8) Nakaseko, K., Yoshida, K., and Yoshida, M.: Physio-ecological studies on potato plant. IX. Varietal differences of productive structure at various population densities. *Mem. Fac. Agric. Hokkaido Univ.*, **8**, 182-187 (1972) (in Japanese with English summary)
9) Sasaki, O.: Development of shoot system in relation to tuberous root formation in sweet potato. 11. Effects of planting density on successive developments of top and tuberous root. *Bull. Fac. of Agr. Kagoshima Univ.*, **No. 41**, 1-6 (1991) (in Japanese)
10) Somda, Z. C. and Kays, S. J.: Sweet potato canopy architecture: Branching pattern. *J. Amer. Soc. Hort. Sci.*, **115**, 33-38 (1990)
11) Somda, Z. C. and Kays, S. J.: Sweet potato canopy morphology: Leaf distribution. *J. Amer. Soc. Hort. Sci.*, **115**, 39-45 (1990)
12) Taylor, H. M.: Root behaviour as affected by soil structure and strength. In: The plant root and its environment (E. W. Carson ed.). *Univ. of Virginia Press*, (*Charlottesville*) pp. 683 (1971)
13) Tsunoda. S., A developmental analysis of yielding ability in varieties of field crops. 11. The assimilation system of plant as affected by the form, direction and arrangement of single leaves. *Jpn. J. Breed.*, **9**, 237 (1959) (in Japanese with English summary)
14) Yamashita, M., Mochida, H., Nimi, H., and Kobayashi, T.: How deep is the system of sweet potatoes? *Jpn. J. Crop. Sci.*, **67** (2), 378-379 (1998)