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Effect of Tree Canopy on the Growth of *Zoysia japonica* Steud. under a Deciduous Forest with Different Tree Densities

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Abstract

The growth of grazed *Zoysia japonica* plants under a deciduous forest at 3 tree densities was investigated. *Z. japonica* sods were transplanted in March 1996. The rooting ratios of *Z. japonica* sods were 75, 86 and 98% under the 3 treatments consisting of low (300 trees/ha), medium (440 trees/ha) and high (630 trees/ha) tree densities (hereafter referred to as "thin, medium and dense treatments"), respectively. The highest rooting ratio recorded under the dense treatment was ascribed to the higher soil water content that was maintained under the dense canopy. Ground coverage of *Z. japonica* increased in all the treatments in the second and third years after transplanting. The most rapid increase in growth and highest dry weight of *Z. japonica* were recorded in the thin treatment with 60% coverage and 573 g/m^2 dry weight in October of the third year. Estimated leaf area index (ELAI) of the trees increased gradually from the first year to the third year in all the treatments. The highest ELAI value was recorded in the dense treatment throughout the experiment. The amount of tree litter decreased from year to year in all the treatments, and no appreciable differences were recognized among the treatments. Therefore, the rooting of transplanted *Z. japonica* under the tree canopy did not seem to be inhibited by shading within the range of the thinning intensities examined, although the growth of *Z. japonica* was more rapid under the low density of 300 trees/ha with an average of 9 m height.

Discipline: Grassland
Additional key words: grazing, litter, rooting, shading, thinning

Introduction

Recently, the number of abandoned forests has been increasing in Japan. The light conditions of the floor of these forests are not adequate and the amount of bottom grass is low because of insufficient thinning management. There is a growing concern that the soil conservation function may decrease in abandoned forests. On the other hand, these forests could be utilized for grazing after thinning.

Gotou et al.[1] demonstrated that the herbage yield of forage plants established on thinned forest floor increased with the thinning intensity. Toda et al.[10] reported that the growth of grasses established on a thinned forest floor varied with the grass species. However, the utilization and palatability of the forage plants grown on forest floors were lower than those of the plants grown in an open area[2].

Zoysia japonica Steud. is one of the dominant species in native pastures in Japan, which could be persistent even without fertilizer application. And the soil erosion preventive function of *Z. japonica* is highly effective because stolons cover the soil surface densely. However, it was observed that the growth of *Z. japonica* was less rapid under shading conditions[4,5]. Therefore, it was considered that the tree density should be reduced so that *Z. japonica* could be established on the forest floor.

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The objective of this study was to examine the growth of *Z. japonica* planted under deciduous forest with different tree densities.

Materials and methods

Study site

The investigations were conducted over a 3-year period (1996–1998) in a forest located in the native grassland (4.1 ha) of the Department of Animal Production of Chugoku National Agricultural Experiment Station in Shimane Prefecture. Altitude of the grassland was about 100 m, annual mean air temperature was 14.6ºC and annual mean rainfall was 1,765 mm. Dominant species in the original forest were oak (*Quercus serrata* Thunb.), Japanese red pine (*Pinus densiflora* Sieb.et Zucc.), storax (*Styrax japonica* Sieb.et Zucc.), wild cherry (*Prunus jamasakura* Sieb., ex Koizd.) and wild walnut (*Platycarya strobilacea* Sieb.et Zucc.).

All the Japanese red pine trees were cut and deciduous trees were thinned into different densities in February 1996. The experimental plots consisted of trees with a low density, "thin plots"(300 trees/ha), medium density, "medium plots" (440 trees/ha) and high density, "dense plots" (630 trees/ha). The plot size was 40 m × 20 m. Mean tree height was 9.1 m and mean diameter at breast height (DBH) was 10.4 cm.

Sods (15 cm × 15 cm) of *Z. japonica* were transplanted at the rate of 1 sod/m^2 in March 1996. This grassland was grazed by 3 Japanese Black Cattle during the grazing season (April–December). The sprouts of the trees that were cut and herbs were trimmed once in 1996 and 1998, and twice in 1997.

Measurements

1. Rooting ratios and growth of *Z. japonica*

The rooting ratio of *Z. japonica* was measured from 100 sods, which were selected randomly in June 1996. Ground coverage of *Z. japonica* and other plants on the forest floor was measured in 3 quadrats (1 m × 1 m).

Top and underground parts (10 cm × 10 cm, 10 cm deep) of *Z. japonica* were taken from each plot at 4 points in October 1998 and washed to remove the soil. The samples were dried at 70ºC for 48 h, and the dry matter weight was measured.

2. Estimated leaf area index and photon flux density

Estimated leaf area index (ELAI) of the trees was measured at a height of 10 cm below the forest canopy with a plant canopy analyzer (LI-COR, LAI-2000) on October 30, 1996 and October 14, 1998. LAI-2000 has been used to measure the estimated LAI of crops and trees[3,11,12]. Direct measurement of LAI in the forests was not conducted in this experiment. ELAI was measured at 1 m intervals on randomly selected 5 straight lines (10 m). ELAI value of each plot expressed the mean.

Photon flux density in the forests was measured at a height of 10 cm below the forest canopy with a quantum sensor (LI-COR, LAI-190SA) during the periods of April 15–May 7 and July 2–31 in 1997. Photon flux density was measured at 3 points of each plot at 60 s intervals and accumulated for 24 h, and the relative photon flux density (RPFD) was calculated.

3. Litter on forest floor

In March and September 1996, and in September 1997 and October 1998, litter was taken from the forest floor in the quadrats (1 m × 1 m) in each plot at 4 points. Litter consisted of tree leaves and branches which remained before thinning and were supplied from the remaining trees. Samples were dried at 70ºC for 48 h.

Results

Rooting ratio, growth of *Z. japonica* and changes in vegetation coverage

Table 1 shows the rooting ratio of *Z. japonica* sods transplanted under a deciduous forest with different tree densities. The rooting ratios of *Z. japonica* sods were 75, 86 and 98% under thin, medium and the dense treatments, respectively. The highest rooting ratio was recorded under the dense treatment.

The changes in the ground coverage of *Z. japonica* and other plants on the forest floor are shown in Table 2. Coverage of *Z. japonica* was considered to correspond to the growth of the aboveground parts of *Z. japonica*. Coverage of *Z. japonica* reached a value of less than 4% in the first year in all the treatments. In the second year, the coverage of *Z. japonica* in the thin treatment was higher than that in the medium and dense treatments. In the third year, the coverage in all the treatments increased, but the most rapid increase was recorded for the thin treatment, with a value of about 60%.

Coverage of other plants (main species were sedge, *Scirpus wichurae*, *Paederia scandens*, *Clinopodium gracile*, *Rhododendron kaempferi*) increased in the first

Table 1. Rooting ratio of *Z. japonica* sods transplanted under a deciduous forest with different tree densities on June 4, 1996

Treatments	Rooting (%)
Thin	75
Medium	86
Dense	98

Table 2. Changes in the coverage of *Z. japonica* and other plants on the forest floor with different tree densities

Treatments	Species	Coverage (%)			
		June 1996	Sep. 1996	Sep. 1997	Oct. 1998
Thin	*Z. japonica*	1.7	3.0	36.7	58.3
	Other plants	38.0	61.4	54.9	37.3
Medium	*Z. japonica*	2.0	2.7	20.0	26.7
	Other plants	35.4	80.6	63.0	65.9
Dense	*Z. japonica*	2.0	3.3	15.0	28.3
	Other plants	28.1	55.6	70.1	58.5

Table 3. Dry weight of *Z. japonica* grown under a deciduous forest with different tree densities on October 29, 1998

Treatments	Dry weight (DWg/m^2)
Thin	573 (413–882)
Medium	514 (470–591)
Dense	397 (360–470)

Each value represents the mean (minimum–maximum).

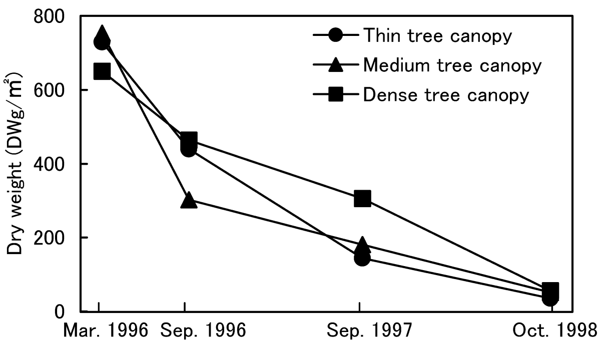

Fig. 1. Changes in the dry weight of tree litter under a deciduous forest

year in all the treatments. In the third year, the coverage of the other plants decreased in the thin treatment.

The dry weight of *Z. japonica* in October 1998 is shown in Table 3. Dry weight of *Z. japonica* in the dense treatment was lower than that in the other treatments.

Light intensity and amount of litter on the forest floor

Values of ELAI of the trees and RPFD of the forest floor are shown in Table 4. Values of ELAI of the trees in October of the first year were 0.40, 0.74, 0.96 in the thin, medium and dense treatments, respectively. In October of the third year, the ELAI of the trees was higher than that in the first year in all the treatments. The highest ELAI value was recorded in the dense treatment throughout the experiment.

The values of RPFD of the forest floor in April–May of the second year were 94.8, 90.6 and 62.4% in the thin, medium and dense treatments, respectively. On the other hand, the RPFD values in July when the tree leaves expanded were lower than those in April–May, i.e. 83.4, 71.4 and 33.0% in the thin, medium and dense treatments, respectively. Also, the variation between the sites in the measurements was within the range of 10% except for the dense treatment in July.

Fig. 1 shows the changes in the dry weight of the tree litter on the forest floor. The dry weight of the litter

Table 4. Estimated leaf area index (ELAI) of trees and relative photon flux density (RPFD) of forest floor of forest canopy with different tree densities

Treatments	ELAI		RPFD (%)	
	Oct. 1996	Oct. 1998	Apr. – May 1997	July 1997
Thin	0.40 (0.15–0.74)	0.49 (0.31–0.68)	94.8 (93.5–96.4)	83.4 (81.4–86.1)
Medium	0.74 (0.58–0.94)	1.10 (1.02–1.18)	90.6 (88.1–92.5)	71.4 (66.1–75.6)
Dense	0.96 (0.75–1.41)	1.31 (1.08–1.52)	62.4 (56.5–65.7)	33.0 (19.6–48.7)

Each value represents the mean (range).

was 650–753 DWg/m^2 after thinning. In September 1996, it was reduced by half in all the treatments. The dry weight of the litter further decreased in the third year, reaching a value of 36–56 DWg/m^2 in October 1998.

Discussion

Effect of tree density on rooting of *Z. japonica*

The rooting ratio of *Z. japonica* determined after transplanting in March was higher under a high tree density. This phenomenon was ascribed to the fact that although precipitation in April 1996 (47 mm) was lower than in average years (113 mm), transpiration from the soil was low under a high tree density, because the amount of solar radiation was also low resulting in a higher soil water content under the dense canopy. Hirayoshi and Matsumura[4] reported that *Z. japonica* died under a 70% shaded treatment. However, the rooting of *Z. japonica* was not restricted at the shading level of the dense treatment. It is assumed that the rooting ratio of *Z. japonica* in the medium and thin treatments should be satisfactory.

Effect of light intensity on the forest floor on the growth of *Z. japonica*

The growth of *Z. japonica* in the thin treatment was more rapid than that in the medium and dense treatments in the second and third years. Also at the site with less shading by trees, *Z. japonica* tended to grow rapidly.

Inoue and Sasaki[5] reported that the shading treatment decreased the coverage and dry yield of *Z. japonica*. In the present study, since the photosynthesis of *Z. japonica* may be restricted in the medium and dense treatments, where the shading level was high, the growth of *Z. japonica* became slower. On the other hand, the light-receiving conditions in the thin treatment were better than those in the medium and dense treatments, as evidenced by the low values of the ELAI of the trees and the high values of the RPFD of the forest floor in the thin treatment. Therefore, in the thin treatment, *Z. japonica* grew quickly because it received a sufficient amount of light. Mitamura et al.[7] reported that *Z. japonica* dominated in grassland with secondary vegetation grazing where *Sasa nipponica* predominated after the forest was cut down. It was considered that since grazing and trimming keep the height of competitive species low, *Z. japonica* should grow well in the thin treatment.

Otsuki et al.[9] indicated that it is necessary for the establishment of a *Z. japonica* grassland to trim weeds or promote intensive grazing in the first or second year. In this study, *Z. japonica* was shaded by trees and other species as the plant length of *Z. japonica* was shorter than that of most of the other species. As a result, trimming improved the light-receiving conditions of *Z. japonica* and may promote the establishment of *Z. japonica* grassland.

The ELAI values of the trees in the thin treatment increased from 0.40 on 1996 to 0.49 in 1998 (Table 4). Consequently, the growth of *Z. japonica* may decline due to the closure of the forest canopy from year to year. Therefore, management of thinning and pruning will be necessary for the maintenance of *Z. japonica* after several years. As tree growth parameters such as tree height and diameter at breast height were not measured after the beginning of the experiment, the effect of thinning and grazing on tree growth could not be analyzed.

In the current experiment, the degree of shading in each treatment was represented by the mean values of ELAI and RFPD which, however, varied from area to area. In the thin treatment, there were few areas with prolonged shading since the intervals between the trees were wide and shaded parts by trees changed with time. Thus, it was considered that *Z. japonica* could spread widely in the thin treatment. In the medium and dense treatments, however, areas were shaded all day long due to the closure of the forest canopy and *Z. japonica* could spread only in areas that received sunlight over a long period of time.

Effect of litter on the forest floor on the growth of *Z. japonica*

In general, a large amount of litter remained on the forest floor. Ogawa et al.[8] reported that fresh tree leaf litter amounted to 690 DWg/m^2, and that litter undergoing decay with soil particles amounted to 2,240 DWg/m^2 on cutover deciduous forest floor. The amount of tree litter that remained at the beginning of the experiment was 650–753 g/m^2, and thereafter the amount of litter decreased from year to year in all the treatments. The decrease of the amount of litter in spite of the litter fall supplied from trees every year was attributed to the decomposition of organic matter which was promoted by the cutting of trees[6] and/or litter distributed by grazing cattle. However, the effect of litter on the soil temperature and growth of *Z. japonica* was not analyzed in this study.

Therefore, the rooting of transplanted *Z. japonica* under the tree canopy did not appear to be inhibited by shading within the range of the thinning intensities examined, although the growth of *Z. japonica* was more rapid under the low density of 300 trees/ha with an average of 9 m height.

References

1. Gotou, M., Sugawara, K. & Hayashi, K. (1982) Productivity of forage plants in the Japanese red pine forest. *J. Jpn. Soc. Grassl. Sci.*, **27**, 381–386 [In Japanese with English summary].
2. Gotou, M., Sugawara, K. & Hayashi, K. (1982) Utilization and palatability of forage plants in the Japanese red pine forest. *J. Jpn. Soc. Grassl. Sci.*, **28**, 330–335 [In Japanese with English summary].
3. Gower, S. T. & Norman, J. M. (1991) Rapid estimation of leaf area index in conifer and broad-leaf plantations. *Ecology*, **72**, 1896–1900.
4. Hirayoshi, I. & Matsumura, M. (1957) Studies on *Zoysia* range I. *J. Jpn. Soc. Grassl. Sci.*, **3**, 16–22 [In Japanese with English summary].
5. Inoue, T. & Sasaki, T. (1958) The effects of shading on sod. *Bull. Tohoku Natl. Agric. Exp. Stn.*, **14**, 92–103 [In Japanese with English summary].
6. Katagiri, S. et al. (1991) Changes on the amount of nutrients returned by litterfall in a sprouting secondary forest. *Bull. Fac. Agric. Shimane Univ.*, **25**, 15–22 [In Japanese with English summary].
7. Mitamura,T. et al. (1985) Studies on *Zoysia* type grassland. V. The effect of different disturbance methods on vegetation dominated by *Sasa nipponica* after clear felling on the establishment of *Zoysia japonica* grassland. *Bull. Natl. Grassl. Res. Inst.*, **30**, 82–90 [In Japanese with English summary].
8. Ogawa, Y., Fukuda, E. & Okamoto, K. (1989) Effect of litter layers on the growth of orchardgrass (*Dactylis glomerata* L.) oversown in the cutover land of deciduous broad-leaved forest. *J. Jpn. Soc. Grassl. Sci.*, **35**, 134–140 [In Japanese with English summary].
9. Otsuki,T. et al. (1984) Studies on movement of *Zoysia*-type grassland. 2. Succession of vegetation and grazing capacity of short grass type grassland under rotational grazing. *Bull. Shikoku Natl. Agric. Exp. Stn.*, **44**, 158–185 [In Japanese with English summary].
10. Toda, T. et al. (1980) The method of pasture development in hard wood forests of mountainous area. *Bull. Iwate Pref. Anim. Husb. Exp. Stn.*, **9**, 1–89 [In Japanese].
11. Welles, J. M. & Norman, J. M. (1991) Instrument for indirect measurement of canopy architecture. *Agron. J.*, **83**, 818–825.
12. Yamamoto, H., Suzuki, Y. & Hayakawa, S. (1995) Estimation of leaf area index in crop canopies using plant canopy analyzer. *Jpn. J. Crop Sci.*, **64**, 333–335 [In Japanese].