The Cooling Effect of Forage Crop, Kudzu (*Pueraria lobata*) Vine Covering over Livestock Buildings

Takuya Koyama[a], Mika Yoshinaga[b], Kei-ichiro Maeda[a] and Akira Yamauchi[a*]

[a] *Department of Biosphere Resources Science, Nagoya University, Nagoya, Japan*
[b] *Department of Architecture, Meijo University, Nagoya, Japan*
[*] *Corresponding author: Nagoya University, Chikusa, Nagoya 464-8601, Japan*
ayama@agr.nagoya-u.ac.jp

Abstract

Heat stress during summer season can decrease livestock productivity, and cause high economic losses to livestock farmers. Although many cooling techniques (e.g. sprinklers, fans, etc.) are available to improve the thermal environment of livestock buildings, they require high construction and energy costs. This research aims to investigate an economical livestock buildings covering method with kudzu (*Pueraria lobata*), which can be used as a cooling technique during summer season and as forage for livestock after use. Kudzu is a fast-growing, climbing and perennial vine, and its shoot can be utilized as high nutritious feed for livestock. In this study, the cooling effect of the covering method with kudzu was investigated by comparing the room temperatures (RTs) between the covered (Covered) and the non-covered fabricated house (height 2.6 m, width 3.65 m, depth 1.83 m) (Non-covered). Two-year-old kudzu seedlings were transplanted beside the south side of the houses in May 2009 and 2010 and induced to climb the plastic nets placed over the south walls and roofs of the houses. RTs of Covered and Non-covered and global solar radiation were measured every 5 minutes during summer season in 2009. The covering rate and the leaf number in 18 frames (0.4 m × 0.4 m each) that were set on the south wall and roof of Covered and stem length were measured every 2 weeks in 2009. The covering rate and the dry weight in 120 frames were measured during autumn 2010. The stem length reached around 4 m long by July 2009. In general, the height of a standard livestock building is around 4 m. These facts showed that two-year-old kudzu seedlings could cover the walls of a standard livestock building during summer season. The estimated average covering rate and leaf number among 18 frames, and the RT differences between Covered and Non-covered showed positively significant relationships (P<.001). The maximum RT difference was observed to be 3.44 °C, when the estimated average covering rate was 43.9 % and the estimated average leaf number was 529 leaves m-2. The covering rate and dry weight in the frame showed a positively significant relationship (P<.001). The maximum dry weight of 253.4 g m-2 was observed when the covering rate was 80.8%. We conclude that the kudzu covering is an effective cooling technique for livestock buildings during summer season and is potentially capable of producing biomass to provide feed for livestock after use.

Keywords: kudzu, green wall, heat stress, livestock productivity, forage crop.

Introduction

The global average surface warming in the 21st century will range from 1.1 to 6.4 °C (IPCC, 2007). The global warming has the potential to occur adverse thermal conditions in the livestock building, which can ultimately reduce productive performance or possibly cause deaths of livestock (Hahn, 1995). Thus, some techniques for environmental modifications such as water misting with spray, forced ventilation with fans or air-conditioning, shading with insulated roof or reflective coated roof are needed to maintain animal production (West, 2003). On the other hand, the employment of these techniques causes higher energy consumption, worsens global warming, and increases general costs for animal production (Nardone, 2010).

The ultimate goal of this study was to establish the economical livestock buildings covering method with the use of kudzu (*Pueraria lobata* (Willd.) Ohwi) vine. That is to cover the walls and roofs of livestock buildings with kudzu vine, which can be used as a cooling technique during summer seasons and as feed for livestock after use.

Kudzu is a fast-growing, climbing and perennial vine. Their vines can grow 10 to 30 m in one growing season (up to 30 cm a day), and create broad canopies (Mitich, 2000). Farmers in the USA cultivated kudzu over a terrace to provide shade in the early 1900s (Tsugawa, 1986). Moreover, kudzu has the wide range of utilization as forage because it is able to provide feed for sheep, swine and chickens as well as cattle (Kristen, 2011). Chemical composition and digestibility characteristics of kudzu were equivalent to other commonly fed forage (Corley *et al*., 1997)

The use of external vegetation can be a useful tool for thermal regulation for buildings. Holm (1989) showed using dynamic computer model that the leaf cover produces a constant 5 °C cooling effect in room temperature in summer. The vegetation consistently lowered the wall surface temperature by about 17 °C, and saved air-conditioning energy as high as 80% (Meier, 1990). However, these studies placed little or no emphasis on the conditions of the plants.

Ip *et al.* (2010) analyzed the shading performance of a vertical climbing plant canopy by measuring number of leaf layers, area of canopy with each leaf layer and solar transmissivity, and established the thermal model that enables to present the shading performance of the climbing plant canopy over its annual growing and wilting cycle. Unlike non-biological devices, the conditions of plant sare affected by not only the characteristics of plants such as leaf area, leaf number, leaf thickness, leaf angle, leaf movement and moisture content of leaves but also the response to the environmental conditions such as solar radiation, ambient temperature, humidity and soil moisture content, which affect the shading performance, the thermal insulation and evaporative cooling produced by transpiration.

The objectives of this paper were to investigate the cooling effect of the dynamic changes of kudzu vine covering by comparing the room temperatures (RTs) between the covered (Covered) and the non-covered container house (Non-covered), and to evaluate the dry matter production of kudzu vine that was used for the economical livestock buildings covering method. The leaf number and covering rate in each frame that was set on the south wall and roof of Covered, the room temperatures of Covered and Non-covered, and environmental conditions around the houses were determined at regular intervals during summer season. At harvest, the covering rate and dry matter weight in 120 frames were measured.

Materials and Methods

Plant materials

Hard-stems (lignified) were collected from kudzu natural stands in the Graduate School of Bioagricultural Sciences, Nagoya University (35°09'N, 135°58'E) from April to May in 2008 and 2009. Then, the hard-stems were cut into around 12 cm with one node and grown in the commercial and artificial soil that is well-drained and poorly nutrient in plastic container (585mm long, 185mm wide and 145mm deep). After cuttings were rooted and sprouted, they were transplanted to plastic pots (25 cm in diameter and 30 cm in height) containing air-dried paddy soil and raised in a glasshouse for one year. In winter 2008 and 2009, all stems were cut at 5cm from the soil surface, and afterwards left undisturbed. Next spring, some buds were sprouted from the rooted cuttings. Sprouted nursery stocks (plant materials) were only used for this study.

Experimental design

Four container houses (2600mm high, 3650mm wide and 1830mm long) were set in series from east to west on the Togo field of the Graduate School of Bioagricultural Sciences, Nagoya University (35°06'N, 137°04'E) in 2009, and 5 container houses were set in 2010. One container house excluding both ends was not covered with kudzu vine (Non-covered), and plant materials were transplanted beside the other container houses in May 25, 2009 and May 24, 2010, and induced to climb the plastic nets (mesh size: 120mm×120mm) placed on the south wall and the roof of the houses.

Measurements

Only two container houses excluding both ends (Non-covered and Covered) were used for evaluating the effect of the dynamic changes of kudzu vine covering on the room temperature reduction in 2009. The houses on both ends were excluded because they received more solar radiation than the inner houses. The stem length, the leaf number and covering rate in each frame (400mm×400mm), which was set on different heights of the south wall (650mm, 1300mm and 1950mm above the soil surface) and on different locations of the roof (465mm, 915mm and 1365mm from the south edge of the roof), were measured on the 3 plants except both ends every 2 weeks from June 10 to September 29, 2009.The estimated average leaf number and covering rate among 18 frames were calculated from the inclination of averages of these data.The room temperatures (RTs) of Covered and Non-covered were recorded every 5 minutes with thermo recorder (TR-72U: A&D Co. LTD.) and global solar radiation was recorded every 5 minutes with pyranometer (MS-801: EKO INSTRUMENT CO., LTD.) from July 15 to September 22, 2009.To evaluate the dry matter production of the economical livestock buildings covering method with use of kudzu vine, the covering rate and the dry weight in 120 frames, which were located on the south wall and the roof of 4 containers, were measured during autumn in 2010.

Image analysis

Before taking digital images of Covered, the white-colored frames (400mm×400mm) were set behind the plants and in front of the south walls and roofs to facilitate processing images. Digital images, composed of 12 megapixel, were obtained with the digital camera (μ-7040: OLYMPUS corporation). The backgrounds except the plants in the frames were cleared manually, and plants were converted into binary image with photoshop (Adobe Photoshop CS2: Adobe). The pixels of the processed image were calculated with imageJ (Public domain software for image processing and analysis in Java). Calculated pixels of the plants and the frames were used for computing the covering rate.

Results and discussion

The stem length reached around 4 m long by July, and some vines exceeded 10 m at the end of August in 2009. In general, the height of a standard livestock building is around 4 m. These facts showed that two-year-old kudzu seedlings could cover the walls of a standard livestock building during summer season.

Fig. 2 shows that the changes in estimated average leaf number and covering rate among 18 frames. The estimated average leaf number gradually increased until the middle of July in 2009. Afterwards, the estimated average leaf number increased rapidly and reached the peak of 530 leaves m-2 on September 10, 2009.The estimated average covering rate showed similar trend with the estimated average leaf number, and it peaked at 45% at the final measurement on September 25.

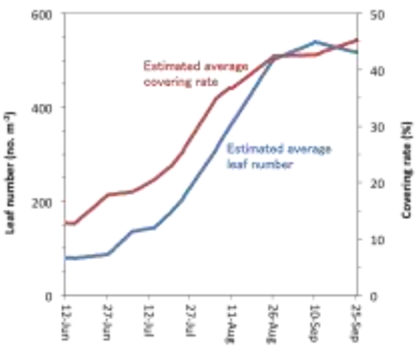
The RTs of Non-covered were clearly influenced by ambient temperature and global solar radiation. The RT differences between Non-covered and Covered were also influenced by ambient temperature and global solar radiation. At the same time, the RT differences tended to gradually increase. Therefore, the data of the RT differences were sorted and averaged out daily according to the global solar radiation; every 0.2 kWM-2; and the processed data were used to highlight the effect of the covering method with kudzu.

Under the global solar radiation conditions less than 0.2 kW m-2, there was a significantly negative relationship between the RT differences, and the estimated average leaf number ($P<.001$) and the estimated average covering rate ($P<.001$). However under the global solar radiation conditions between 0.2 kW m-2 and 1.0 kW m-2, there were significantly positive relationships between the RT differences, and the estimated average leaf number ($P<.001$) and the estimated average covering rate (P<.001). The inclinations of each regression equations increased as the global solar radiation increased under the global solar radiation conditions between 0.2 kW m-2 and 1.0 kW m-2. The maximum RT difference was observed to be 3.44 °C, when the estimated average covering rate was 43.9 % and the estimated average leaf number was 529 leaves m-2. The covering rate and dry matter weight in the frame showed a positively significant relationship (P<.001). The maximum dry weight of 253.4 g m-2 was observed when the covering rate was 80.8%.

We conclude that the kudzu covering is a possible cooling technique for livestock buildings during summer season and is potentially capable of producing biomass to provide feed for livestock after use.

This photo was taken on September 18, 2009.

Figure 1. Two container houses(2600mm high, 3650mm wide and 1830mm long) excluding houses on both ends (*Non-covered* and *Covered*) were used for evaluating the effect of the dynamic changes of kudzu vine covering on the room temperature reduction in 2009.



The estimated average leaf number and covering rate were calculated from the inclination of averages of leaf number and covering rate among18 frames (400mm×400mm), which were located on the south wall and roof of *Covered*.

Figure 2. Changes in the estimated average leaf number and covering rate among 18 frames in 2009.

References

Corley, R. N., Woldeghebriel, A. and Murphy, M. R. 1997. Evaluation of the nutriative value of kudzu (*Puerarialobata*) as a feed for ruminants. *Anim. Feed Sci. Technol*. 68: 183-188

Hahn, G.L.1995. Environmental management for improved livestock performance, health and well-being. *Jpn. J. Livest. Management*, 30(3): 113-127.

Holm, D. 1989.Thermal improvement by means of leaf-cover on external walls –a simulation model. *Energ. Build*. 14:19–30.

Ip, K., Lam, M., Miller, A. 2010. Shading performance of a vertical deciduous climbing plant canopy. *Build. Environ.* 45: 81–88

IPCC (The Intergovernmental Panel on Climate Change).2007. Climate change 2007: Synthesis Report 2007..Geneva, Switzerland. Pp52.

Kristen, H. 2011. KUDZU. *Am. Hist.* 46 (2): 38-44

Meier, A. K. 1990.Strategic landscaping and air-conditioning savings: a literature review. *Energ. Build*. 15–16:479–486.

Mitich, L. W. 2000. Intriguing world of weeds - Kudzu (Pueraria lobata (Willd.) Ohwi). *Weed tech*. 14: 231-235

Nardone, A., Ronchi, B., Lacetera, N., Ranieri, M.S., Bernabucci, U. 2010.Effects of climate changes on animal production and sustainability of livestock systems. *Livest.Sci.*130: 57-69.

Tsugawa, H. 1986a. Cultivation and utilization of kudzu-vine (*Pueraria lobata* OHWI) taxonomy, geographical distribution, use, breeding and propagation. *J. Japan.Grassl. Sci*.31(4): 435-443.

West, J.W. 2003. Effects of heat stress on production in dairy cattle.*J. DairySci.* 86: 2131– 2144.

-- back to Table of Content --