EMERALD ZOYZIA GRASS DEVELOPMENT REGARDING PHOTOSYNTHETICALLY ACTIVE RADIATION IN DIFFERENT SLOPES

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ABSTRACT: With this study, the objective was to estimate the photosynthetically active radiation (PAR) and to correlate it with the dry matter (MMSPA) of the emerald zoysia (*Zoysia japonica* Steud.) on surfaces with different expositions and slopes. The research was conducted at the Experimental Watershed of the Agricultural Engineering Department, School of Agriculture and Veterinary Sciences of São Paulo State University (FCAV/UNESP), Brazil, where the surfaces (H, 10 N, 30 N, 50 N, 10 S, 30 S, 50 S, 10 L, 30 L, 50 L, 10 O, 30 O and 50 O) were used. To obtain the global solar radiation, it was installed an automated weather station where the PAR (dependent variable) was obtained by the equation y = a + bx, and the global radiation was independent. To compare means of MMSPA, it was used the Tukey test at 5% probability, and to assess the relation PAR/MMSPA, the simple linear correlation coefficient. The result showed that the accumulation of these effects in the PAR increases with North exposure and decreases with the South, and exposure to 50N is most suitable for slopes, not having correlation between the PAR and the MMSPA for the surfaces evaluated for the study period.

KEYWORDS: *Zoysia japonica*, slope, solar radiation.

DESENVOLVIMENTO DA GRAMA-ESMERALDA EM RELAÇÃO À RADIAÇÃO FOTOSSINTETICAMENTE ATIVA EM DIFERENTES DECLIVIDADES

RESUMO: Com este trabalho, o objetivo foi estimar a radiação fotossinteticamente ativa (PAR) e correlacioná-la com a massa de matéria seca (MMSPA) da grama--esmeralda (*Zoysia japonica* Steud.), em superfícies com diferentes exposições e declividades. A pesquisa foi desenvolvida na Bacia Hidrográfica Experimental do Departamento de Engenharia Rural, FCAV/UNESP, Brasil, onde foram utilizadas as superfícies (H; 10 N; 30 N; 50 N; 10 S; 30 S; 50 S; 10 L; 30 L; 50 L; 10 O; 30 O e 50 O). Para a obtenção da radiação solar global, foi instalada uma estação meteorológica automatizada, onde a PAR (variável dependente) foi obtida por meio da equação y = a + bx, e a radiação global foi a independente. Para comparação de médias da MMSPA, utilizou-se o teste de Tukey, a 5% de probabilidade, e para verificar a relação existente PAR/MMSPA, o coeficiente de correlação linear simples. O resultado mostrou que o acúmulo desses efeitos na PAR aumenta com a exposição norte e decresce com a sul, sendo a exposição 50 N a mais indicada para taludes, não havendo correlação entre a PAR e a MMSPA para as superfícies avaliadas para o período estudado.

PALAVRAS-CHAVE: *Zoysia japonica*, taludes, radiação solar.

INTRODUCTION

The highways have raised the production chain to an important niche and new landscaping, i.e., the coating of road works with large slopes and areas for rest; in these cases, it was always used Bahia grass (*Paspalum notatum Flügge*), however, gradually, it has been replaced by Emerald Zoysia (*Zoysia japonica Steud*.), which is widely cultivated in Brazil, while the Bahia grass is

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obtained through the extraction of large areas usually distant from the site of implantation, presenting transport and logistics problems (COAN, 2007).

The word GRASS has its origin in the name of the botanical family of grasses (Gramineae = Poaceae), which encompasses more than 10,000 species scattered throughout the world, considering that the most important ones serve as human consumption, such as rice, corn and wheat, or as animal consumption, such as Brachiaria, and there are others which are used even in buildings, such as bamboo, however, less than 50 species of grasses may be used to form lawns (WATSON & DALLWITZ, 1992). Among the species of grasses adapted to Brazilian climatic conditions, there are: Blanket grass (*Axonopus compressus*), or Bahia grass (*Paspalum notatum*), St. Augustine or Buffalo Grass (*Stenotaphrum secundatum*) and Emerald (*Zoysia japonica*) (PIMENTA, 2003). “In Brazil, they are commonly called Emerald Zoysia or Japanese lawn grass and they are, in general, scientifically identified as *Z. japonica*. Recently, ANDERSON (2008) and SHOULIANG & PHILLIPS (2006) established taxonomic keys that allow the identification of the main representatives of the genre, but for cultivars, this task is difficult because the hybrids have characteristics of more than two species. What is called the Emerald Zoysia in Brazil is not the *Emerald* cultivar developed in the United States. Based on taxonomic keys (ANDERSON, 2008; SHOULIANG & PHILLIPS, 2006), it may be a hybrid of *Z. japonica* x *Z. matrella*. From the first, the Emerald grass shows similarity to the pedicel length and leaf width. The other characteristics, such as size and shape of the spikelet, internode length, position of the leaves, spikelet length x width ratio, correspond to the description of *Z. matrella*.”

Besides the aesthetic effect that they give to parks and gardens, lawns may also form pasture, cover sports fields, such as golf and soccer, act in slope stabilization in erosion control, among other purposes (ANGELIS NETO & ANGELIS, 1999; LORENZI, 2000; RAVEN et al., 2001; FREITAS et al., 2002; BUSEY, 2003).

The lawns are used to control soil erosion, and they are six times more effective in the absorption of rain water than a crop of wheat, and four times more effective than hay. The amount of grassed area lost sediment is ten times smaller than the straw coverage. Proper maintenance of a lawn provides a comfortable and safe environment, and contributes to improving air quality, reducing the global warming trend (VILLAS BOAS & GODOY, 2007).

Many grass species used nowadays were developed from pastures and rangelands. However, lawns deployed today, with grass species and hybrids of great beauty, are a long way from its predecessors, requiring, therefore, special care in its maintenance. Among these precautions, there is the constant need for grass clippings, fertilizer, soil aeration, irrigation and weed control (ARRUDA, 1997).

Cutting slopes and landfill landslides are common every year in rainy periods, especially in areas of steeper topography. When it comes to road slopes, as well as to natural slopes adjacent to highways, such events often cause damage, and often break up in traffic with serious damage to users and public authorities (DER, 1991).

The quantification of the incident radiation and the understanding of its effect on the functioning of various physiological processes are fundamental to settle an expected crop production and so they may propose management practices that enable the best use of this and other resources (LEITE, 1996).

The relation between the production of dry matter and the amount of photosynthetically active radiation (PAR) intercepted has been widely used to define the efficiency of radiation use by crops (SIVAKUMAR & VIRMANI, 1984; COSTA et al., 1996).

Slope has been studied by several authors as an interference in the photosynthetically active radiation interaction in relation to the production of dry matter in different species as (C3): sorghum (BENINCASA, 1976), Coastcross grass (LOPES, 1986), and saccharine sorghum (DAMASCENO et al., 1993), but there are no references about this interference in ornamental and sports lawns.

For the proper development of the grass is of fundamental importance that irrigation is carried out efficiently, focusing on the optimization of water resources. In the specific case of irrigation in grasses, it is observed that the use of water resources has been carried out without any scientific basis. According to DACOSTA & HUANG (2006), many irrigators assess the time to carry out irrigation in a visual way, without adopting any strategy for rational use and management of irrigation water.

In literature, there are recommendations for fixed frequencies of irrigation for each crop. While it may be practical in the sense of programming operations, this method leads to deficits and excesses of water, since climatic conditions vary from year to year. Thus, there is a need to use field methods to determine, directly or indirectly, the soil water availability for crops, according to the environmental conditions prevailing during plant development (FARIA & COSTA, 1987).

According to COAN et al. (2008), although the Emerald grass is of great commercial and ornamental interest, there are still many questions related to the speed of establishment. For BARBOSA et al. (1997), quoted by MACIEL et al. (2008), the fact of ornamental plants and lawns have little importance recognized by the research institutes in the Country, results in lack of technical information, eagerly sought after by potential users, resulting in their uncontrolled import and/or generalization of solutions and recommendations with no scientific basis.

With this study, the objective was to estimate the incident photosynthetically active radiation (PAR) accumulated and to correlate it with the dry matter on surfaces with different expositions and slopes, with Emerald grass.

MATERIAL AND METHODS

The research was developed in the experimental area of Department of Rural Engineering, School of Agriculture and Veterinary Sciences of São Paulo State University (FCAV/UNESP), located at 21º14’05” South Latitude, 48º17’09” West Longitude, and altitude of 613.68 m, in a structure called “Experimental Watershed”, described in detail by TURCO (1998). The climate according to Köeppen is Cwa, i.e., subtropical dry winter. The daily data of mean temperature and mean relative humidity of air, mean barometric pressure and rainfall were obtained from the Meteorological Station of FCAV/UNESP, located approximately 200 meters of that Watershed (Table 1).

TABLE 1. Monthly meteorological data in the winter/2007. Jaboticabal, State of São Paulo, Brazil, 2008.

Month	Pressure (hPa)	Tmax (ºC)	Tmin (ºC)	Tmean (ºC)	RH (%)	Rainfall (mm)	ND	Insolation (h)
June	947.2	27.7	13.5	19.5	69.1	2.5	01	268.4
July	946.5	26.4	12.8	18.5	68.8	87.7	05	248.5
August	947.0	29.6	14.1	21.0	58.1	0.0	00	311.4
September	946.0	32.7	17.3	24.3	50.8	0.4	02	287.1

Source: Data provided by Weather Station of FCAV/UNESP. * T = temperature; RH = relative humidity and ND = number of cloudy days.

It was used 13 boxes constructed of masonry measuring 3.0 m x 3.5 m (10.5 m^2). The experiment was carried out from June to September, 2007. The surfaces of each treatment were characterized as: H (horizontal surface) 10 N, 30 N, 50 N, 10 S, 30 S, 50 S, 10 L, 30 L, 50 L, 10 O, 30 O and 50 O, whose simulation is representative of land with slopes and exposures commonly used for planting of Emerald grass.

The experimental area soil is the type LE1, dark red, eutrophic, moderates A, kaolinitic, hipoferric, clayey, wavy soft relief (Eutrustox) (ANDRIOLI & CENTURION, 1999).

In 2006, the boxes were packed with homogenized soil, taken from the surface layer of 0.30 m in an area of forest soil and with similar characteristics to the local soil, and the volume of each box corresponded to 5.25 m^3, with the following main chemical characteristics: pH = 5.6 ($CaCl_2$), MO = 14.0 (g dm^{-3}), and V% = 65.0. No liming and fertilization were done due to pH and V% was in the range of indicated recommendation for grass culture.

Pre-planting procedures were carried out starting by the sampling of the soil, followed by the preparation of ground, based on the operations of cleaning area, clean field, followed by lump breaking and soil fluffing, to a depth of 0.50 m. The soil from each box were removed for subsequent placement of the soil described above, where it passed through screening for homogenization. At the end, leveling of the area and a thorough cleaning of the surroundings were carried out. The planting was done by carpets (0.40 m x 1.25 m), joining with each other and compressing them with a socket of iron plate of 0.006 m.

To determine the frequency of irrigation, three tensiometers were installed at a depth of 0.10 m (area of greatest concentration of grass roots), centered on a straight line, perpendicular to slope and off the floor area of sampling.

In practice, to determine when it was necessary to irrigate, It was proceed as follows: while the readings are greater than - 0.5 atm, it is not necessary to irrigate. Once the voltage is more negative than - 0.5 or - 0.6 atm, it was proceed to the irrigation. Is that when a soil on which a culture is in full development reaches potentials of the order of - 0.5 to - 0.6 atm, almost all available water has been lost, and within one to two days, the potential passes abruptly to - 10 to - 15 atm, affecting crop productivity (REICHARDT, 1990). In this experiment, when the average of the readings of the tensiometers was equal to - 0.5 atm, it was performed drip irrigation, through the installation of six perforated hoses of 3.5 m long, provided with holes in its entirety, apart 0.2 m from each other.

The amount of water applied to each surface was function of ETo values obtained by Penman-Monteith method (ALLEN et al., 1998), adjusted for each surface.

The assessments were made monthly, from November 2006, after the complete installation and stabilization of the lawn, removing four samples (replicates) per treatment. For that, it was used a mobile network of iron, with meshes measuring 0.12 m x 0.12 m, covering every floor area of the box (except for boundary). It was drafted the samples for each treatment (from 1 to 4), carried to the reading of the leaf height. Then it was cut the shoot, where they were placed in paper bags and placed for drying in an oven of forced air renewal at 70°C for determination of dry matter mass of shoots (COAN, 2005). After collection of samples, each treatment received maintenance cut using a portable motorized mower of Sthil brand, model FS 220, and this operation was repeated monthly.

To obtain the global solar radiation, it was installed near the experimental area an automated weather station of Campbell Scientific, Inc. brand, and to obtain solar radiation on the surfaces studied, measured from the horizontal, the methodology developed by Kondratyev (1977) were used. The incident photosynthetically active radiation was estimated on surfaces using the equation of GEROLINETO (2005), described below:

$$PAR = -0.257 + 0.4237\ Ss \quad (1)$$

In which,

PAR - photosynthetically active radiation, MJ m^{-2} d^{-1}, and

Ss - incident global solar radiation, MJ m^{-2} day^{-1}.

Data from PAR and dry matter were submitted to regression analysis and considering the linear model y = a + bx, where the dependent variable data were obtained for dry matter mass, while the data of photosynthetically active radiation were the independent variable. The dry matter was obtained by the average of four replications of each treatment (g) and then transformed to (g dm^{-2}). To assess the relation between PAR and MMSPA, we used the simple linear correlation coefficient.

The experimental design was completely randomized. The treatments were arranged in a factorial 3 x 4 + 1, with three slopes (50; 30 and 10%), four exposures (North, South, East and West) and a control on a flat surface with four replications. Each treatment refers to a bed of 10.5 m^2, where the Emerald grass was grown.

RESULTS AND DISCUSSION

The production of dry matter mass permits the evaluation of the growth of a plant, according to FELFILI et al. (1999), quoting LOGAN, is the best growth rate, and it is used to evaluate the conditions required by the species. Analyzing Table 1 and crossing with the information contained in Figures 1 and 2, we see that the month of September 2007 showed the highest maximum temperature (32.7 °C), minimum temperature (17.3°C), and the MMSPA was the highest value for the second largest PAR radiation given in the same month for 50 N. The lowest maximum temperature (26.4 °C), minimum temperature (12.8 °C), rainfall (87.7 mm) and cloudy days (5 days) were given in July 2007, and the MMSPA was the least exposure value for L 10 and the lowest PAR radiation given in the same month.

CHANG (1968) corroborates this study agreeing that the total amount of radiation received at the surface of a ramp varies according to exposure and tilt, being its direct component influenced by both and its diffuse component only by tilting, so that on cloudy days, the effect of exposure is minimized as shown in Table 1.

LOPES (1986), who studied the effects of topography on the variation of incident solar radiation and production of forage (*Cynodon dactylon (L.) Pers. Cv. Coastcross I*), concluded that: the slope, in each exposure, was less effective in altering the production of green mass and dry matter than the exposures. BENNET et al. (1972) quoted by TURCO (1998), studied on 40° North Latitude on ramps with slopes of 35% the effect of North and South exposures on a typical temperate climate grass, *Poa pratensis L.*, with different levels of nitrogen. They observed that the production on the ramp exposed to the North was twice the ramp with Southern exposure, the same being presented in this work, where exposure 50 N showed twice the value shown by the 10 S. It was reported in this study that the cause of this difference is the high soil temperature, and that the moisture reduction occurred on the ramp with South exposure due to higher incidence of radiation and also to have used a species adapted to regions of low values of the elements considered.

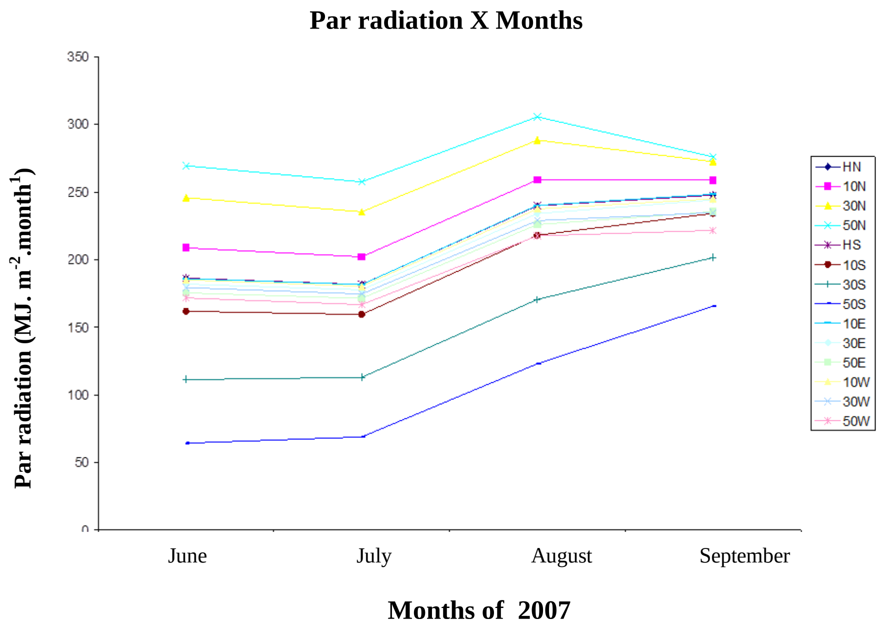
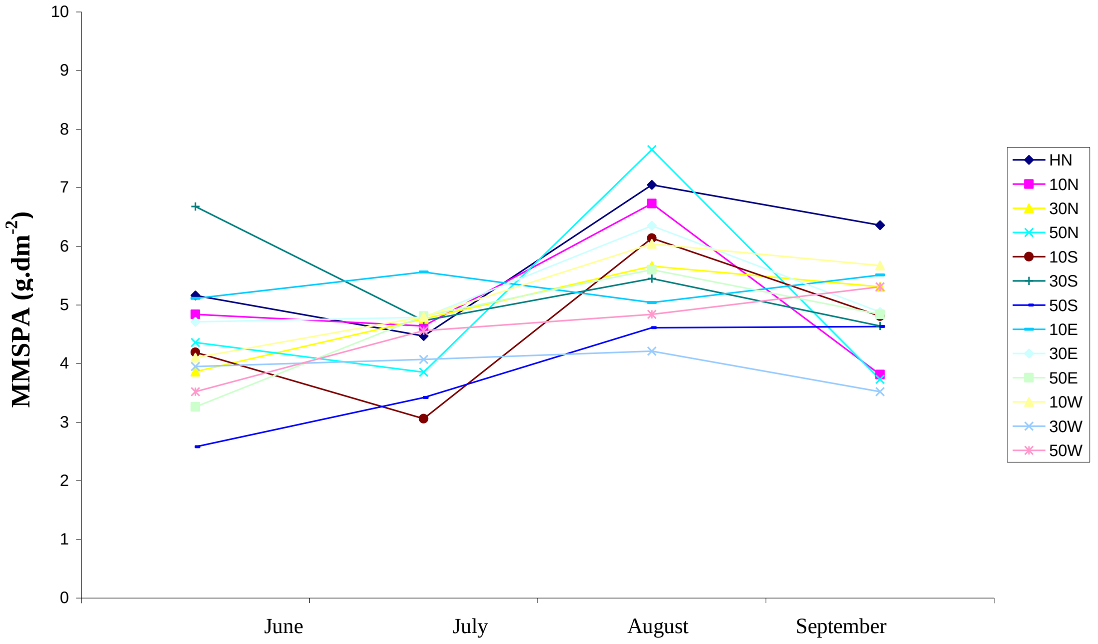


FIGURE 1. PAR Radiation (MJ m^{-2} month^{-1}) for the period of the trial on the basis of the surfaces.

LATANZE (1973), studying the effect of exposures North and South on land with slopes of 10% on bean (*Phaseolus vulgaris L.)*, latitude 21°, in Jaboticabal, State of São Paulo, concluded that the variety Carioca was sensitive to microclimate changes caused by small variations in the ground. The productions of the North exposure were higher than the South exposure, as shown in this study.

MMSPA X Months



Months of 2007

FIGURE 2. Mass of dry matter of shoot (MMSPA) for the period of the trial on the basis of the surfaces.

BENINCASA (1976), in experiments carried out in the same experimental watershed mentioned above, working with the ramps 0, 10, 20, 30, 40 and 50%, with North and South exposures, in sorghum culture (*Sorghum bicolor (L.) Moench*.), concluded that, in times of the year with lower availability of solar radiation, the effect of the ramp was so steep that allowed to obtain, simultaneously, different microclimatic conditions, affecting significantly the behavior of the culture, both in growth and in development, and this observation was noted by this study and confirmed by Table 1.

LOPES (1986) found in working with the Coastcross I grass that increases in soil temperature at 0,005 m depth caused decreases in the mass production of green matter and especially of dry matter. The mass production of green matter decreased by exposure in order from North, West, East and South, both as to the annual season, and for this study, in order from North, South, East and West.

Thus, the results obtained in the quoted studies corroborate with this study, so that the slope in each exposure were less effective in altering the production of dry matter than the exposures; the productions of the surfaces of North exposure were higher than the South exposure.

By means of Table 2, there was no correlation between the MMSPA and PAR during the period of November 2006 to October 2007 for the surfaces evaluated, and in Table 3, the same occurred in the period studied.

TABLE 2. Pearson correlation coefficient (r) depending on the data of dry matter mass of shoots (g m^{-2}) and radiation (PAR: MJ m^{-2} $month^{-1}$) for each surface assessed during the period of November 2006 to October 2007. Jaboticabal, State of São Paulo, 2008.

Surfaces	r	t	p
50 N	- 0.2577	0.2174^{NS}	0.8323
30 N	- 0.2210	0.1584^{NS}	0.8773
10 N	0.2104	0.1432^{NS}	0.8890
H	0.6664	1.8836^{NS}	0.0890
50 S	0.6555	1.7995^{NS}	0.1021
30 S	0.4666	0.7786^{NS}	0.4543
10 S	0.5957	1.3971^{NS}	0.1926
50 L	0.3093	0.3181^{NS}	0.7569
30 L	0.4546	0.7337^{NS}	0.4800
10 L	0.3131	0.3265^{NS}	0.7508
50 O	0.4327	0.6567^{NS}	0.5262
30 O	0.4327	0.6567^{NS}	0.5262
10 O	0.2601	0.2216^{NS}	0.8291

^{NS} = Not significant ($p>0.05$). r = correlation coefficient. t = t test for H_0: r = 0. p = probability = 0.05.

TABLE 3. Pearson correlation coefficient depending on the data of dry matter mass of shoots (g m^{-2}) and radiation (PAR: MJ m^{-2} $month^{-1}$) for each month assessed during the period of November 2006 to October 2007. Jaboticabal, Brazil, 2008.

Months	r	t	p
June	0.0701	0.0178	0.9862
July	0.0645	0.0138	0.9892
August	0.5825	1.3847	0.1936
September	0.0126	0.0005	0.9996

r = correlation coefficient. t = t test for H_0: r = 0. p = probability= 0.05.

CONCLUSIONS

The slopes studied in each exposure were less effective in altering the dry matter mass of shoots (MMSPA) than the exposure, decreasing in the order North, South, East and West for the period studied, being higher for North than for South.

During winter, the area recommended for the cultivation of Emerald Zoysia to obtain further development is the one which presents higher slopes and North exposure (50 N) for covering slopes and guides the grass cultivators for the production of grasses on sloping surfaces.

The dry matter mass of shoots (MMSPA) of Emerald Zoysia does not correlate in a direct way with the PAR in order to quantify photosynthesis, therefore, soil and other climatic factors are involved in this measurement, and they may not be measured, not having correlation between the MMSPA and PAR to the surfaces evaluated and for the period studied.

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