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Assessment of morphological characteristics and quality of turfgrass *Zoysia matrella* accessions from Indonesia

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Abstract. *Rahayu, Herawati A, Herdiansyah G, Putri RAAAK, Sofyan A, Muttaqin Q. 2024. Assessment of morphological characteristics and quality of turfgrass* Zoysia matrella *accessions from Indonesia. Biodiversitas 25: 4950-4960. Zoysia matrella* is a popular turfgrass species suitable for tropical climates, including Indonesia. However, there are challenges related to the selection of accessions that produce the best quality. This research aimed to assess the morphological characteristics and visual and functional quality of turfgrass *Z. matrella* collected from various origins in Indonesia. The study combined exploratory surveys to collect *Z. matrella* accessions across Indonesia and was continued by laboratory experiments at Universitas Sebelas Maret, Central Java, using a Completely Randomized Design (CRD). We used 16 accessions of *Z. matrella* from 8 provinces in Indonesia to be compared with two commercials, imported accessions as controls. Results showed that Z. *matrella* accession from Sampit, Central Kalimantan showed the highest plant height of 10.22 cm, the longest root length of 15.72 cm, and the percentage of coverage was 94.06%. Conversely, accession from Marina Semarang had the shortest plant height of 8.35 cm with a percentage of cover of 72.75%. Some local accessions of Z. *matrella* had comparable visual and functional quality, growth, and morphology characteristics to the commercialized accessions, opening possibilities for the development of new, high-quality *Z. matrella* cultivars native to Indonesia.

Keywords: Indonesian accession, morphology, quality, *Zoysia matrella*

INTRODUCTION

Turfgrass or ground-cover grass is increasingly popular in modern society along with the growing demand for green spaces for lawns, recreational areas, and sports facilities like soccer, golf, baseball, and softball fields (Cheng et al. 2014). In Indonesia, the demand is evident from turfgrass used in the 2023 World Cup U-17 and 180 golf courses with an average size of 70 hectares each (Juliantika and Wicaksono 2017). Along with the increasing demand for turfgrass in Indonesia, efforts are needed to develop native Indonesian grasses with the best quality. Well-managed grasses must meet criteria such as growing tightly covering the soil, having smooth leaves, having strong and deep root systems, and withstand short-cutting and trampling (Turgeon 1996). Nonetheless, the development of turfgrass in Indonesia faces several problems, such as the suitability of grass species with the growing media and climatic conditions in Indonesia.

Turfgrass evaluation is generally based on visual and aesthetic factors, such as leaf color, tiller density, leaf texture, turf uniformity, smoothness, and growth habit, as well as quality for use, like resilience, wear tolerance, and drought tolerance, salinity tolerance, and recovery rate. Grass quality is evaluated on a scale from 1-9 based on visual and functional aspects like root length, root dry weight, shoot dry weight, and surface cover percentage (Agnihotri et al. 2017; Rahayu et al. 2020a). Turfgrass quality can be enhanced through management techniques to ensure player comfort, reduce injuries, and improve the aesthetic appeal of grass beds, thereby increasing business value (Straw et al. 2020). Commonly, the better wear tolerance of turfgrass is associated with an increase in the number of vascular bundles, leaf width, leaf cross-section area, and leaf angle. Turfgrass wear resistance is improved along with wider leaves, a higher number of vascular bundles together, and a higher angle between the leaf and tiller axis (Głąb et al. 2015). According to Brosnan et al. (2005), more vertical leaf angles of turfgrass will result in greater wear tolerance. Overall, turfgrass quality and wear tolerance are associated with anatomical and morphological characteristic traits of the above-ground part of grasses (Głąb et al. 2015).

Indonesia's tropical climate, with high temperatures, intense sunlight, and year-round rainfall, is ideal for native grass species like *Zoysia matrella* (L.) Merr., *Z. japonica* Steud., *Cynodon dactylon* (L.) Pers. and *Paspalum vaginatum* Sw. (Rahayu 2022). Such germplasms are valuable for breeding and developing cultivars that adapt to the environment and advance the grass industry (Rahayu et al. 2023). Among the germplasms, *Z. matrella,* also known as Manila grass, is a drought-resistant summer grass that thrives in tropical regions such as Indonesia (Lin et al. 2020). This grass is used in several Indonesian stadiums, including Maguwoharjo Sleman, Si Jalak Harupat, and Gelora Bangkalan (Paripurno 2014). *Zoysia matrella* also grows naturally in various locations across Indonesia, such as beaches, roadsides, and mountainous areas (Rahayu et al. 2014). The ability of *Z. matrella* to thrive in various soil conditions and hot climates, combined with its beauty and durability, makes it a popular choice for landscape applications such as soccer, golf, and athletic fields (Huang et al. 2016). Although *Z. matrella* grows slowly and takes longer to cover areas, this slow growth reduces mowing frequency and maintenance costs (Ramírez-Suárez and Hernández-Olivera 2016).

Besides species selection, the choice of growing media is also important in the cultivation of turf grass. One of the potential growing media for *Z. matrella* is river sediments resulting from the deposition of natural materials due to erosion and then carried by river flow (Wohl 2015). River sediment is dominated by clay and mud which is caused by severe erosion in the outer river arch; material with fine particles in the eroded outer arch will be carried away and deposited on the inner arch. In comparison, material with coarser particle sizes between 0.2 to 0.6 mm settles and remains on the riverbed. This particle size is classified as sand texture (Maulana et al. 2018). Sand-textured media are preferred in the turfgrass industry due to their permeability and aeration, which support root growth better than high-density soils (Rahayu et al. 2018). Sand-textured soils offer good drainage, which prevents puddling and soil compaction that can cause player injuries and hinder play (dos Santos and de Castilho 2018). Such media improve grass quality by enhancing nutrient, water, and oxygen absorption, especially when combined with fertilizers (Stewart et al. 2017).

This research aimed to evaluate the morphological characteristics of several accessions of *Z. matrella* from various origins in Indonesia when they were grown on river sediments. This research is important as few have explored the morphological traits and quality of *Z. matrella* native to Indonesia, particularly from Java, Bali, Kalimantan, Sulawesi, and Maluku compared with imported commercial cultivars. The research results can potentially revolutionize the turfgrass industry in Indonesia by guiding in selecting quality turfgrass cultivars that can compete with commercial grass types, thereby improving the quality and sustainability of turfgrass in the country.

MATERIALS AND METHODS

Plant materials

This study used an exploratory survey to collect plant materials and was continued by experimental research. Several accessions of *Z. matrella* grass were collected randomly from various locations in Indonesia, namely Java, Bali, Kalimantan, Sulawesi, and Maluku (Figure 1; Table 1). The grass samples were collected on the stolon, packed in plastic bags and brought to Jumantono Laboratory, Faculty of Agriculture, Universitas Sebelas Maret, Central Java, Indonesia. At the laboratory, the grass samples were planted in pots for one month. The stolons and tillers were then harvested from the pots and then planted in the experimental plot. The growing medium used was sand sediment from the Bengawan Solo River.

Experimental procedures

The experiment used a Completely Randomized Design (CRD). The treatments consisted turfgrass accessions. There were 16 accessions of *Z. matrella* wild-type and two commercial cultivars (i.e. Zeon and Zmeet) (Table 1) with each accession having three replicates, resulted in a total of 54 experimental units. The grass was planted in seedling pots containing 50 holes measuring 5 cm × 5 cm × 5 cm of each unit. The grass was planted in the holes using three tillers, and each tiller had stolons with a length of three internodes. During the growth period, the grass was irrigated with fresh water twice a day. Turfgrass was planted on growing media of river sediment collected from Bengawan Solo River. The characteristics of river sand Sediment (S) are shown in Table 2.

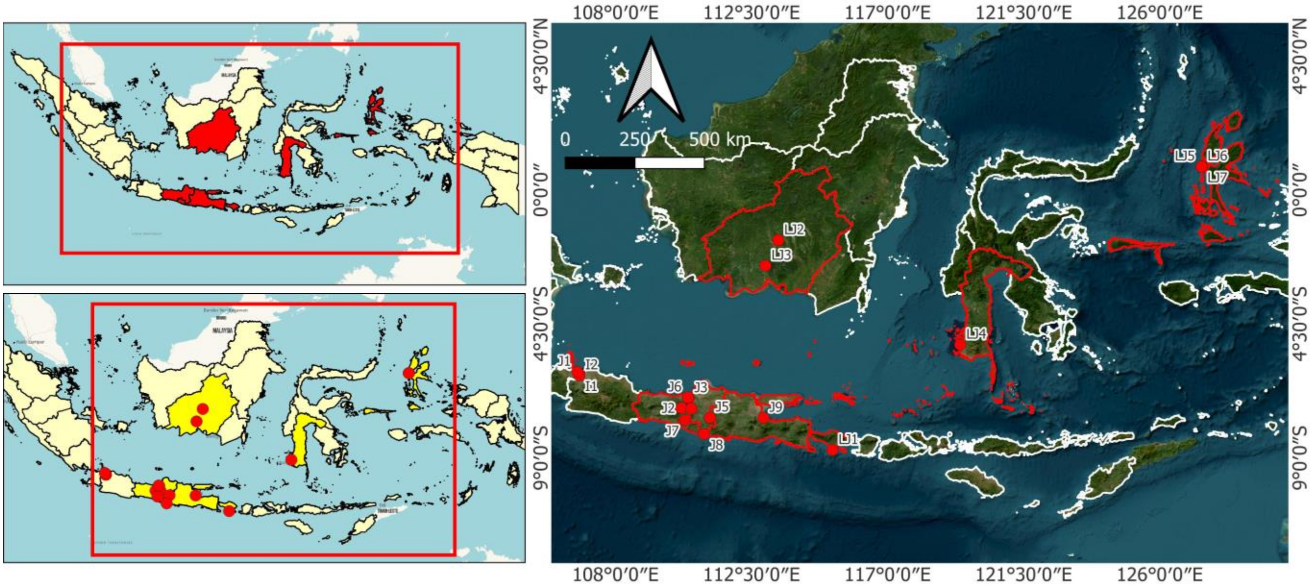

Figure 1. Map showing the material sources of *Zoysia matrella* grass collected from eight provinces in Indonesia

Table 1. Sampling locations of *Zoysia matrella* from eight provinces in Indonesia

Grass sample location	**Province**	**Code**	**Latitude**	**Longitude**	**Altitude (msl)**
Indah Kapuk Beach (SJ1)	Jakarta	J1	6°06’09.83” N	106°44’3.73” E	3
Temanggung (SJ2)	Central Java	J2	7°18’59.57" N	110°10’31.79” E	589
Simpang Lima Semarang (SJ3)	Central Java	J3	6°59’25.64” N	110°25’21.30” E	5
Salatiga (SJ4)	Central Java	J4	7°19’49.23” N	110°30’00.77” E	577
Jumog Karanganyar (SJ5)	Central Java	J5	7°37’39.21” N	111°^{0}7’02.16” E	906
Marina Raya Semarang (SJ6)	Central Java	J6	6°57’44.30” N	110°23’37.94” E	2
Seyegan Sleman (SJ7)	Yogyakarta	J7	7°43’15.85” N	110°18’31.79” E	171
Donorojo Pacitan (SJ8)	East Java	J8	8°11’35.95” N	110°55’54,13” E	189
Pasuruan (SJ9)	East Java	J9	7°38’58.03” N	112°54’06.92” E	8
Kuta Bali (SLJ1)	Bali	LJ1	8°43’36.38” N	115°10’49.03” E	3
Central Kalimantan Unipandanwangi (SLJ2)	Kalimantan	LJ2	2°28’19.94” N	112°13’55.69” E	38
Sampit Central Kalimantan (SLJ3)	Kalimantan	LJ3	2°32’16.89” N	112°57’40.20” E	3
Makassar Outer Fort (SLJ4)	Sulawesi	LJ4	5°08’03.47” N	119°24’18.18” E	3
Maliaro Ternate Tengah (SLJ5)	Maluku	LJ5	0°47’12.52” N	127°22’51.82” E	28
T.F.Oranje Ternate Tengah (SLJ6)	Maluku	LJ6	0°47’31.37” N	127°23’16.13” E	3
G.K.Raha Ternate Tengah (SLJ7)	Maluku	LJ7	0°47’07.31” N	127°22’55.67” E	21
Zeon (SI1)	Imported from USA (Gelora Bung Karno)	I1	6°13’07.00” N	106°48’06.00” E	12
Zmeet (SI2)	Imported from Thailand	I2	6°13’10.00” N	106°48’15.00” E	12

Table 2. Characteristics of river sand sediment collected from Bengawan Solo River used in this study

Parameters	**Unit**	**Results**	**Value**
Permeability	cm/hour	11.75**	Medium to fast
Texture			
Sand	%	88.30***	Sand
Loam	%	7.02***	
Clay	%	4.68***	
BV	g/cm^3	1.52****	Very High
Porosity	%	41.75*****	High
ECp	dS/m	0.243*	Very Low
pH H_2O	-	7.00*	Neutral
C-Organic	%	0.24*	Very Low
N-Total	%	0.11*	Low
P-Available	ppm	2.23*	Very Low
K-Available	me/100 g	0.18*	Low

Notes: **: Value according to Lal (1994), Wander et al. (2002), Ministry of Forestry Regulation Number: P.32/MENHUT-II/2009 (2009), Soil Research Institute Rating (2009), and Soil Research Institute (2012)

The observed parameters in this study were plant morphological characteristics and visual and functional quality of turfgrass (Table 3). The final step of grass quality assessment is using the National Turfgrass Evaluation Program (NTEP). The NTEP aims to assess the performance of grass species both visually and functionally (Agnihotri et al. 2017). The assessment of each parameter as presented in Table 3 considers the lower and upper limits of each score in each parameter, except for leaf color. Values in the range between the lower and upper limits of each parameter were calculated using the following equation:

$$Score = \frac{smin+((n-nmin)x\,(smax-smin))}{(nmax-nmin)} \text{.........Equation (1)}$$

Where :

smin : Lowest score

smax : Highest score

n : Value (observation result for each parameter)

nmin : Lower limit (the lowest value in the range)

nmax: Upper limit (the highest value in the range)

The visual quality final score is the average of the leaf width score, grass density and leaf color. The final score of functional quality is the average root length, root dry weight, shoot dry weight and final cover percentage (Agnihotri et al. 2017; Rahayu et al. 2023). Before calculating the average final score of visual and functional quality, the observation variables of leaf color, root length, root dry weight, and shoot dry weight were first converted from the old range to the new range with the NTEP rating scale, which is 1 to 9 using linear transformation. Leaf width is assessed based on the width of the leaf blade, the narrower it is, the higher the score, indicating better visual quality. Grass density is assessed by the number of shoots per unit area; the more shoots/tillers, the higher the score value, indicating better visual quality. Leaf color is assessed based on the level of greenness. The darker the color, the higher the score. Leaf angle is measured with a protractor based on the vertical position of the stem as a reference. Leaves that stand straight up have the smallest leaf angle, while lateral leaves have a large leaf angle.

The score assessment of the old range and the new range of each observation variable is presented in Table 3.

$$Linear\ transformation\ y = \frac{(b-a)\times(x-xmin)}{(xmax-xmin)} + a \text{...... (2)}$$

From the linear transformation formula above, for each visual and functional quality observation variable, the following equation is obtained:

$Leaf\ Width\quad y = x$ ……………………….……... (3)

$Grass\ Density\quad y = x$ ……………………………... (4)

$Leaf\ Color\ \ y = 2x - 1$ ……………………………. (5)

$Percentage\ Coverage\quad y = x$ ………………..…... (6)

$Root\ Dry\ Weight\quad y = 4x - 3$ ……………….…… (7)

Table 3. Visual and functional quality scoring of *Zoysia matrella* used in this study

Parameter	Value	Old score range	New score range
Visual quality			
Leaf width	≥0.4 cm	1	1
	≤0.1 cm	9	9
Grass density	≤25 tillers/25cm^2	1	1
	≥50 tillers/25cm^2	9	9
Leaf color	2.5 GY 6/6	1	1
	2.5 GY 6/4	2	
	2.5 GY 5/6	3	
	2.5 GY 5/4	4	
	2.5 GY 5/2	5	9
Functional quality			
Root length	≤10 cm	1	1
	≥23 cm	4	9
Root dry weight	≤0.75 g/25cm^2	1	1
	≥1.75 g/25cm^2	3	9
Shoot dry weight	≤0.63 g/25cm^2	1	1
	≥0.88 g/25cm^2	3	9
Percentage coverage	0 %	1	1
	100 %	9	9

$$Shoot\ Dry\ Weight\ \ y = 4x - 3 \qquad \text{(8)}$$

$$Rooot\ Length\ \ y = \frac{8(x-1)}{3} + 1 \qquad \text{(9)}$$

Where:

y : Score value in the new range
b : New range max value
a : New range minimum value
x : Score value in the old range
xmax: Maximum value old range
xmin: Minimum value old range

Thus, the average formula for the final visual and functional quality assessment is as follows:

$$\text{Visual quality score} = \frac{\text{Equation 3} + \text{Equation 7} + \text{Equation 9}}{3}$$

$$\text{Functional quality score} = \frac{\text{Equation 6} + \text{Equation 7} + \text{Equation 8} + \text{Equation 9}}{4}$$

The additional measurement of morphology is leaf angle (°), measured between the leaf and tiller axis, using a manual angle caliper and ruler.

Statistical analysis

Data was analyzed using ANOVA and followed by Duncan Multi Range Test (DMRT) to see the statistical difference among the accessions. We used SPSS for the statistical analysis.

RESULTS AND DISCUSSION

Soil characteristics

After being planted with *Z. matrella,* there were some changes on the sand sediment planting media with the results of the laboratory presented in Table 4. The ANOVA showed that the accessions of *Z. matrella* native to Indonesia had a very significant effect ($P<0.01$) on soil properties of Bulk Density (BD), porosity, ECp, pH H_2O, and C-Organic. The soil BD of all treatments was classified as very high-medium and decreased. The BD ranged from 1.52-1.36 gr/cm^3 with the highest BD of Marina Raya Semarang accession (SJ6) was significantly different from Zeon accession (SI1) which had the lowest BD. Porosity is inversely proportional to BD; if BD is high, then porosity is low, and vice versa (Wahyuni et al. 2023). This premise is in line with the research results, where the highest soil porosity value of the Zeon accession (SI1; 48.87%) was significantly different from the Marina Raya Semarang accession (SJ6; 44.31%), which had the lowest porosity. The BD and porosity results showed that the growth habits of both types of grass were different, where Semarang accession could grow in more compact media and tended to have higher survivorship. High porosity determines how quickly or slowly water and air seep into the soil. Sand-textured soils have macro pores so that water and air infiltrate very quickly but are difficult to retain because there is enough space for water to move (Huang and Hartemink 2020). Sand-textured media is often used by turfgrass managers as a single planting medium or mixed with other planting media.

The amount of organic carbon shows the amount of organic matter in the soil, which is important for soil fertility because it produces humus, which can bind and store nutrients and water. The soil C-organic value of all accessions increased, although it was still at the same level, which was very low. The increase in C-organic value is thought to be the contribution of organic matter from vegetation debris and microorganisms in the environment around the experimental plot. Vegetation debris is able to contribute organic matter in the soil, assisted by the activity of microorganisms to break it down (Dignac et al. 2017). The higher the organic matter content and soil porosity, the lower the soil BD value (Akbar et al. 2023); C-organic is inversely proportional to BD and directly proportional to porosity. C-Organic values tend to be higher; the soil is crumbly. Results showed that the highest-lowest C-Organic value ranged from 0.86-0.26% with the highest was in Zeon accession (SI1), significantly different from Marina Raya Semarang accession (SJ6) which had the lowest. When the media was applied with the same organic matter, and after several mounts, the lower organic matter remained, showing that Semarang accession absorbed nutrients from organic matter better than Zeon, thus potentially allowing for more survival and faster growth. Sand has a low C-organic value because sand has a small surface area of soil colloids to trap organic minerals, and macro pores make nutrients easily leached (Roa et al. 2024). Sand-textured soils tend to have low organic matter, so they are less able to retain water. Grass growth media generally contain 80-100% sand. Sand-textured media is often used in sports fields because it has better drainage and aeration. Good aeration means air circulation is sufficient for plants. Sand macro pores can reduce the risk of waterlogging and soil compaction, thus minimizing the occurrence of player injuries and finally facilitating ball movement (Biraderoglu et al. 2020). However, sand-textured media for sports fields is not entirely ideal because it has weaknesses, i.e. it is less able to retain water and nutrients, so it needs extra maintenance, such as adding fertilizers.

High-salinity soil inhibits the absorption of nutrients and water by plants. Soils with high salinity can inhibit cell elongation and reduce shoot biomass (Zhang and Hu 2021). The highest soil electric conductivity (ECp) value was in Sampit Central Kalimantan accession (SLJ3) and was significantly different from Marina Raya Semarang accession (SJ6), which had the lowest. ECp showed that nutrients or salt remained in the soil solution; thus, the grass had a lower ECp in the soil after several months. However, grass absorbed nutrients faster than marine grass, which had a higher ECp. Thus, Marine grass could potentially grow faster than Sampit accession. The ECp of sandy sediment soils tends to be very low. ECp value <1 dS/m is very low, so plants can still tolerate the salt content, while ECp >4 dS/m can reduce crop productivity due to increased osmotic pressure (Putra et al. 2021). Zoysia grasses are generally moderately tolerant to salinity, but *Z. matrella* is more salinity tolerant than *Z. japonica* (Patton et al. 2017). pH H_2O of sand-textured soil had a value that tends to be neutral. Neutral pH causes macronutrients such as nitrogen, phosphorus, and potassium will be more available and can be absorbed by plants (Gondal et al. 2021). The highest pH value of Marina Raya Semarang accession (SJ6) was significantly different from Zeon (SI1) which had the lowest pH. This trend is the same as that of BD, porosity, and ECp, where the Marina Raya Semarang accession has potentially higher survival and faster growth than the other accessions.

Morphological characteristics

The results showed that the accessions of *Z. matrella* native to Indonesia had a very significant effect (P<0.01) on the length of stolons, plant height, leaf angle, and flower length at 13-16 Weeks After Planting (WAP) as presented in Table 5. Stolons grow from lateral buds on the crown or crown of grass horizontally along the soil surface to form roots and shoot into new grass tillers (Turgeon 1996). Stolon length and plant height of all accessions showed significant differences every week and increased every week from the age of 13-16 WAP (Figures 2 and 3). The longest stolon and plant height when 13 WAP-16 WAP accession was TF Oranje Ternate Tengah accession (SLJ6) and significantly different from the Marina Raya Semarang accession (SJ6), which had the lowest stolon and shortest plant height. Zoysia grasses from different locations have different stolon branching sizes, but generally, *Z. matrella* is shorter than *Z. japonica* (Loch et al. 2017). Sand textured media affects stolon length due to sand having proper aeration and drainage and macro pores that reduce soil density, creating optimal conditions for plant growth (Springer et al. 2014). Sand media can increase the rate of stolon growth and better root development (Magni et al. 2017).

The highest plant height value when 14, 15, and 16 WAP was the accession of Sampit Central Kalimantan (SLJ3), which was significantly different from the accession Marina Raya Semarang (SJ6). The results showed there were variations in the highest and lowest plant height when 13 WAP-16 WAP. Differences in plant height are due to genetic factors and environmental conditions, such as different temperatures between accessions (Tanaka et al. 2016). In addition, environmental conditions such as rainfall, cultivation techniques, and nutrient availability also affect plant height (Khan et al. 2022). Macro pores dominate sand soils and, therefore, have good aeration, and oxygen levels in the soil are related to soil aeration (Ben-Noah and Friedman 2018). Oxygen is needed by plant roots for respiration, which is beneficial in supplying energy for growth and supporting the absorption of nutrients from the soil to the roots, so aeration is important to support plant growth (Ma et al. 2022).

Table 4. Soil properties of sand sediment growing media after being planted with various accessions of *Zoysia matrella*

Accession code	BD (g/cm^3)	Porosity (%)	EC (dS/m)	pH H_2O	C-Organic (%)
SJ1	1.46 abcd	46.47 e	0.310 cdef	6.83 cdef	0.66 ef
SJ2	1.51 abc	44.48 g	0.257 gh	6.90 abcd	0.36 hi
SJ3	1.44 d	47.69 bc	0.340 abc	6.72 efg	0.77 bc
SJ4	1.46 abcd	45.60 f	0.303 def	6.85 bcd	0.61 f
SJ5	1.51 abc	44.35 g	0.267 gh	6.97 ab	0.34 ij
SJ6	1.52 a	44.31 g	0.247 h	6.99 a	0.26 k
SJ7	1.48 abcd	44.55 g	0.277 fgh	6.93 abc	0.40 h
SJ8	1.45 cd	46.73 e	0.320 bcde	6.82 cdef	0.70 de
SJ9	1.45 cd	47.24 d	0.327 abcd	6.80 defg	0.74 cd
SLJ1	1.45 cd	47.50 cd	0.333 abcd	6.80 defg	0.75 cd
SLJ2	1.47 abcd	44.72 g	0.287 efg	6.87 abcd	0.54 g
SLJ3	1.37 e	48.72 a	0.357 a	6.59 hi	0.83 ab
SLJ4	1.44 d	47.50 cd	0.340 abc	6.71 fg	0.77 bc
SLJ5	1.48 abcd	44.64 g	0.280 fgh	6.88 abcd	0.51 g
SLJ6	1.43 d	47.93 b	0.350 ab	6.69 gh	0.80 bc
SLJ7	1.46 bcd	46.66 e	0.307 cdef	6.83 cde	0.67 ef
SI1	1.36 e	48.87 a	0.353 ab	6.52 i	0.86 a
SI2	1.51 ab	44.32 g	0.253 gh	6.97 ab	0.29 jk

Notes: The mean in the column followed by the same letter indicates not significantly different based on the DMRT test at the confidence level (95%)

Table 5. Morphological characteristics of various accessions of *Zoysia matrella* 16 Weeks After Planting (WAP)

Accession	Stolon length (cm) 16 WAP	Plant height (cm) 16 WAP	Leaf angle (°)	Spikel length (cm)
SJ1	1.84 cde	9.40 d	68 abc	1.25 ef
SJ2	1.65 ef	8.37 g	67 bc	1.29 def
SJ3	2.14 a	10.19 a	64 bcdef	1.54 ab
SJ4	1.78 de	9.40 d	61 cdef	1.26 ef
SJ5	1.66 ef	8.37 g	66 bcd	1.18 ef
SJ6	1.53 f	8.35 g	56 fg	1.33 cde
SJ7	1.74 de	8.58 f	65 bcdef	1.26 ef
SJ8	1.81 cde	9.97 b	63 bcdef	1.44 bcd
SJ9	1.92 bcd	9.90 b	62 cdef	1.31 def
SLJ1	2.12 ab	10.16 a	61 cdef	1.55 ab
SLJ2	1.76 de	9.35 d	53 g	1.62 a
SLJ3	2.15 a	10.22 a	64 bcdef	1.33 cde
SLJ4	2.01 abc	10.18 a	75 a	1.26 ef
SLJ5	1.71 ef	8.97 e	64 bcdef	1.16 f
SLJ6	2.15 a	10.21 a	65 bcde	1.21 ef
SLJ7	1.80 de	9.54 c	70 ab	1.47 bc
SI1	2.09 ab	10.16 a	57 efg	1.19 ef
SI2	1.63 ef	8.36 g	58 defg	1.54 ab

Notes: The mean in the column followed by the same letter indicates not significantly different based on the DMRT test at the confidence level of 95%

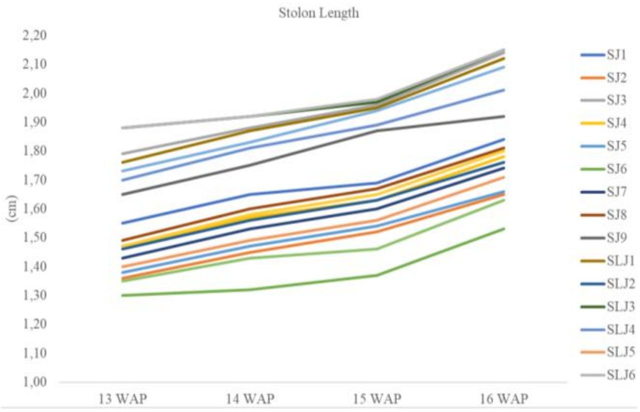

Figure 2. Stolon growth of various accessions of *Zoysia matrella* at the 13 to 16 Weeks After Planting (WAP)

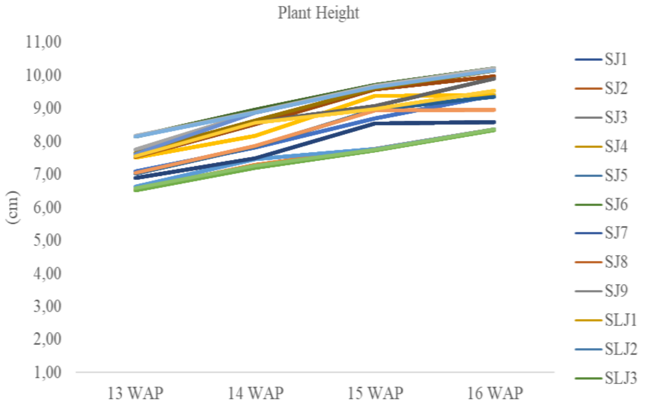

Figure 3. Height growth of various accessions of *Zoysia matrella* at the 13 to 16 Weeks After Planting (WAP)

Table 5 shows that only 4 of 18 accessions were not different in term of stolon length. Zeon had a longer stolon node than the others, except with Simpang Lima Semarang, Kuta Bali, Sampit Central Kalimantan, Makassar Outer Ford, and TF Oranje Ternate. Zmeet had a short stolon and was similar to Maiaro Ternate, Marina Raya Semarang, and Temanggung. The change in stolon length after planting is steady in comparison between import cultivars and the wild type. The longer stolon of turfgrass in early planting became steady after several weeks (Figure 2). In general, shorter stolon will produce a higher density of tiller, resulting in compacter turf. However, turfgrass with longer stolon will rapidly cover the soil surface. Okeyo et al. (2011) reported that stolon elongation has a positive correlation to stolon branching, a process where new stolon grows from existing ones to cover the soil surface. Patton et al. (2007) also reported that zoysia grass had faster stolon elongation and thus had more rapid establishment.

Leaf angle affects the quality of turfgrass in supporting ball roll. Horizontal leaf angle turf is ideal because creates a smooth surface with better coverage and low mowing tolerance and will facilitate ball rolling (Chen et al. 2016). The horizontal angle will receive optimal sunlight required for photosynthesis (Turgeon 1996). The highest leaf angle value of the Makassar Outer Fort accession (SLJ4) was significantly different from the Central Kalimantan Unipandanwangi accession (SLJ2) which had the lowest leaf angle. Leaf angles that tend to be perpendicularly horizontal occurred on the accessions of SI1, SI2, SLJ2, SJ6, SJ4, SLJ1, SJ9, SJ8, SLJ5, SLJ3, SJ3, SJ7, SLJ6 and SJ5. While the other accessions, SJ2, SJ1, SLJ7, and SLJ4, tended to have leaf angles that tended to be vertical. Genetic and environmental factors can cause differences in leaf angle (Müller-Linow et al. 2015). Turfgrass with more vertical leaf angle will result in greater wear tolerance (Brosnan et al. 2005). Głąb et al. (2015) reported that the better wear tolerance of turfgrass is associated with the higher angle between the leaf and tiller axis and, together with a higher number of vascular bundles. Spikelets are a series of flowers consisting of one or more florets arranged on one main axis (Turgeon 1996). The highest flower length was produced by the Central Kalimantan Unipandanwangi accession (SLJ2; 1.62 cm) and was significantly different from Maliaro Ternate Tengah accession (SLJ5; 1.16 cm), which had the lowest flower length. Different environmental and genetic conditions between accessions influence the difference in flower length between accessions (Lee et al. 2013). *Zoysia matrella* has a single spikelet length of 1.00-2.10 cm (Tsuruta et al. 2010), which is in line with the result of this study.

Visual and functional quality parameters

The analysis of variance showed that the accessions of *Z. matrella* grass native to Indonesia had a very significant effect (P<0.01) on leaf width, tiller density, and leaf color (Table 6). Leaf width is a measurement of the leaf blade width of the grass. The difference in leaf width between accessions affects the quality of turfgrass because narrower leaves facilitate ball movement and improve field aesthetics. At the same time, non-uniform leaves can reduce the beauty and slow down ball movement (Kazemi et al. 2020). The highest leaf width value of Zmeet (SI2) (0.17 cm) was significantly different from Zeon (SI1) (0.12 cm) which had the lowest leaf width. The *Z. matrella* accessions native in this study are within the category of fine or narrow leaf width. Differences in leaf width between species and origin are thought to be due to the influence of different cultivation techniques and environmental factors such as drought, fertilization, mowing, and irrigation (Rahayu 2022).

Leaf color is the amount of light reflected by the grass. Each person has a different preference for leaf color. Leaf color adds the beauty of grass beds; dark green leaf color is considered to have better aesthetic quality than bright green (Głąb et al. 2020). In this study, grasses from various accessions showed significant differences in leaf color. The highest score of leaf color was produced by the Sampit Central Kalimantan accession (SLJ3), which was significantly different from the Marina Raya Semarang accession (SJ6), which had the lowest score of leaf color. Differences in grass species and origin produce different leaf color variations from light to dark green due to the genetic influences they carry and the environment where they grow (Lee et al. 2016). *Zoysia matrella* leaf color tends to be dark green (Brosnan et al. 2008). A brighter color can caused by the lack of nitrogen elements, drought, water shortages, temperature stress, and pest attacks (Rahayu et al. 2023; Adams et al. 2024).

Grass density is defined as the number of shoots (tiller) per unit area. The highest grass density was Zeon (SI1), and significantly different from Marina Raya Semarang accession (SJ6), which had the lowest grass density. Soils with a high percentage of sand reduce soil compaction, thus increasing grass density that can improve quality (Correa et al. 2019). Sand-textured soils have good aeration and drainage for grass growth (Li et al. 2019).

The accession of *Z. matrella* grass had a significant effect (P<0.01) on root length, root dry weight, shoot dry weight, and final cover percentage at 12 WAP. Good rooting is expected to improve the quality of grass beds. Grasses with long roots are more resistant to stress and high physical damage. Sand-textured soil has better aeration where there is more oxygen in the root area. This aeration affects root elongation in sand-textured soil (Malleshaiah et al. 2017). The highest root length was produced by Sampit Central Kalimantan accession (SLJ3), which was significantly different from Marina Raya Semarang accession (SJ6), which has the lowest root length. Roots extend in search of nutrients needed for plant growth. Plants obtain more nutrients by extending their roots toward the nutrient source (Sathiyavani et al. 2017). Root dry weight is related to the length of rooting in the soil. A well-aerated medium increases the ability of roots to absorb nutrients, water, and oxygen needed to survive drought stress (Balliu et al. 2021). Aerated pores in sand provide high root development so that it can increase root dry weight; longer roots make grass able to survive physical damage such as trampling. The highest root dry weight was produced by Sampit Central Kalimantan accession (SLJ3), which was significantly different from Marina Raya Semarang accession (SJ6), which has the lowest root dry weight. Root dry weight affects grass productivity and is related to root density (Katuwal et al. 2021).

Shoot dry weight is used to measure grass growth that is influenced by maintenance, irrigation, and other environmental factors. The highest shoot dry weight value of the TF Oranje Ternate Tengah accession (SLJ6) was markedly different from the Marina Raya Semarang accession (SJ6), which recorded the lowest shoot dry weight. Good aeration in the sand medium supports the growth of stolon and root, with the nodes on the stolon segments serving as sites for new shoots to grow. This process results in more new shoots above the soil surface, thereby increasing the dry weight of the shoots. Stolon, in addition to supporting shoot growth, also serve as sites for root growth, further contributing to the overall shoot dry weight (Rahayu et al. 2023). The real difference in shoot dry weight among grass origins can be caused by grass growth in different species that will affect the dry weight of the grass. Different grass growth can be influenced by cultivation techniques such as maintenance, irrigation, fertilization, and other environmental factors (Aldous et al. 2014).

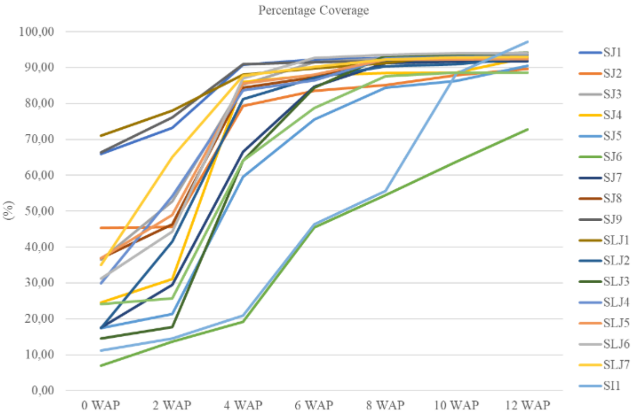

Figure 4. The growth in term of percentage coverage of various *Zoysia matrella* accessions until 12 Weeks After Planting (WAP)

Table 6. Visual and functional quality parameters of various *Zoysia matrella* accessions

Accession	Visual quality parameter			Functional quality parameter			
	Leaf width (cm)	**Grass density (Number of tiller/25cm^2)**	**Leaf color (Score)**	**Root length (cm)**	**Root dry weight (gr/25cm^2)**	**Shoot dry weight (gr/25cm^2)**	**Percentage coverage (%) 12 MST**
SJ1	0.15 cd	50 cd	4.33 ab	10.55 efgh	0.71 gh	0.64 def	92.77 a
SJ2	0.17 ab	45 de	3.33 cd	9.45 gh	0.58 jk	0.55 g	89.56 a
SJ3	0.13 efg	62 abc	4.67 ab	13.97 abc	1.01 ab	0.83 ab	93.87 a
SJ4	0.14 de	53 bcd	4.00 bc	11.21 defg	0.81 ef	0.67 de	92.85 a
SJ5	0.16 b	45 de	3.33 cd	9.63 gh	0.61 ijk	0.57 fg	90.53 a
SJ6	0.17 a	29 f	3.00 d	8.99 h	0.52 k	0.53 g	72.75 b
SJ7	0.16 bc	45 de	3.33 cd	10.06 fgh	0.67 ghi	0.59 efg	91.86 a
SJ8	0.15 cd	53 bcd	4.33 ab	12.13 cde	0.85 de	0.76 bc	92.93 a
SJ9	0.14 def	57 bcd	4.33 ab	12.83 bcd	0.89 cde	0.71 cd	93.04 a
SLJ1	0.14 def	59 bcd	4.67 ab	13.82 abc	0.95 bc	0.80 ab	93.71 a
SLJ2	0.16 bc	46 cde	4.00 bc	10.35 efgh	0.75 fg	0.65 def	92.72 a
SLJ3	0.13 gh	67 ab	5.00 a	15.72 a	1.10 a	0.85 a	94.06 a
SLJ4	0.13 fgh	62 abc	4.67 ab	15.30 a	1.05 a	0.80 ab	93.27 a
SLJ5	0.15 cd	46 de	3.33 cd	9.73 gh	0.64 hij	0.60 efg	92.39 a
SLJ6	0.13 fgh	75 a	4.67 ab	14.40 ab	1.02 ab	0.88 a	94.01 a
SLJ7	0.14 de	54 bcd	4.33 ab	11.70 def	0.93 bcd	0.69 cd	92.97 a
SI1	0.12 h	77 a	4.67 ab	14.93 a	1.07 a	0.82 ab	97.20 a
SI2	0.17 a	34 ef	3.00 d	9.21 h	0.54 k	0.54 g	88.63 a

Notes: The mean in the column followed by the same letter indicates not significantly different based on the DMRT test at the confidence level of 95%

Table 7. Score of visual quality assessment of various accessions of *Zoysia matrella*

Accession	Leaf width score	Grass density score	Leaf color score	Visual quality score
SJ1	7.76	8.68	4.33	8.03
SJ2	7.22	7.29	3.33	6.73
SJ3	8.11	9.00	4.67	8.48
SJ4	7.84	7.61	4.00	7.49
SJ5	7.40	7.29	3.33	6.79
SJ6	7.04	2.17	3.00	4.74
SJ7	7.49	6.33	3.33	6.50
SJ8	7.76	8.79	4.33	8.07
SJ9	7.93	8.89	4.33	8.16
SLJ1	7.93	9.00	4.67	8.42
SLJ2	7.49	7.61	4.00	7.37
SLJ3	8.29	9.00	5.00	8.76
SLJ4	8.20	9.00	4.67	8.51
SLJ5	7.76	7.72	3.33	7.05
SLJ6	8.20	9.00	4.67	8.51
SLJ7	7.84	9.00	4.33	8.17
SI1	8.47	9.00	4.67	8.60
SI2	7.04	3.88	3.00	5.31

Percentage coverage shows the proportion of soil surface covered by grass and indicates the growth rate of turfgrass. The fastest closure rate is generally preferred to facilitate quick use and to provide better comfort when being used (Juliantika and Wicaksono 2017). The percentage coverage experienced increased growth and development every week from the age of 0 WAP-12 WAP (Figure 4). The highest coverage at 12 WAP was produced by Zeon (SI) accession (97.20%), significantly different from the Marina Raya Semarang (SJ6) accession (72.75%), which had the lowest coverage. The difference in coverage is presumably due to differences in the growth of stolon, new shoots, and roots; which is influenced by the ability to adapt to the environment. High stolon growth rates will produce more new shoots, which will accelerate coverage more evenly (Gaetani et al. 2017; Rahayu et al. 2020b).

Visual and functional quality assessment

Visual and functional quality assessment is an evaluation method used to assess the condition and performance of turfgrass beds. The turfgrass industry refers to the National Turfgrass Evaluation Program (NTEP) developed by Morris and Shearman to assess turfgrass quality (Agnihotri et al. 2017). Turfgrass researchers and experts use observational data to assess the visual and functional qualities based on NTEP (Kazemi et al. 2024). Turfgrass quality assessment is conducted by trained evaluators using the NTEP method with a standardized rating scale from 1 to 9, where 1 indicates the worst quality, and 9 indicates the best quality. These evaluations are subjective based on the expertise judgment so that ratings can vary between evaluator (Wolski et al. 2021). Grass species that have good visual and functional qualities are the first choice (Agnihotri and Chawla 2017). The results of the assessment of the visual quality of *Z. matrella* accessions are presented in Table 7. The Sampit Central Kalimantan (SLJ3) accession had the highest final score of visual quality with a score of 8.76, which is higher than commercial grass Zeon (SI1) and Zmeet (SI2) with 8.60 and 5.31, respectively.

Functional quality assessment is to ensure that the grass has good use or function. Root length is assessed from the base to the longest tip; the longer the root, the higher the score, indicating better functional quality. Heavier root dry weight and shoot dry weight result in a higher score, indicating better functional quality (Table 8).

Table 8. Score of functional quality assessment of various accessions of *Zoysia matrella*

Accession	Root length score	Root dry weight score	Shoot dry weight score	Cover percentage score	Functional quality score
SJ1	1.13	1.00	1.11	8.42	3.05
SJ2	1.00	1.00	1.00	8.16	2.79
SJ3	1.92	1.51	2.61	8.51	5.61
SJ4	1.28	1.11	1.33	8.43	3.49
SJ5	1.01	1.00	1.00	8.24	2.82
SJ6	1.00	1.00	1.00	6.82	2.46
SJ7	1.07	1.00	1.01	8.35	2.90
SJ8	1.49	1.21	2.05	8.43	4.45
SJ9	1.65	1.27	1.71	8.44	4.28
SLJ1	1.88	1.39	2.43	8.50	5.28
SLJ2	1.12	1.05	1.20	8.42	3.18
SLJ3	2.32	1.69	2.81	8.53	6.27
SLJ4	2.22	1.61	2.43	8.46	5.71
SLJ5	1.03	1.00	1.04	8.39	2.90
SLJ6	2.01	1.55	2.89	8.52	6.00
SLJ7	1.39	1.37	1.49	8.44	3.98
SI1	2.14	1.64	2.49	8.78	5.84
SI2	1.00	1.00	1.00	8.09	2.77

The cover percentage indicates the ability of the grass to cover the area; the higher the percentage thus higher the score. Sampit Central Kalimantan (SLJ3) accession had the highest functional quality with 6.27, higher than the commercial grasses Zeon (SI1) and Zmeet (SI2) with 5.84 and 2.77, respectively. The selection of planting media for grass beds is important because planting media can affect grass growth and quality (Głąb et al. 2016).

In conclusion, the study revealed that the native Indonesian *Z. matrella* accession from Sampit, Central Kalimantan (SLJ3) had the highest visual and functional quality. On the other hand, the Marina Semarang accession had the highest survival and faster growth than the other accessions. These results open possibilities for the development of new, high-quality *Z. matrella* cultivars native to Indonesia. Proper turf management can help native grasses become stronger and adapt to climate and environmental changes (Toledo et al. 2014). Germplasm is a substance carrying hereditary traits or genetic traits possessed by plant species to be propagated or developed into new cultivars. Screening native germplasm genotypes through the plant breeding process to find or create superior parent strains and hybrids that can adapt to the surrounding environment. This will help develop the turfgrass industry in the future (Rahayu et al. 2023).

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