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Research Article

Preliminary selection of some ecotypes of *Cynodon dactylon* (L.) Pers. in Sabah, Malaysia, for turfgrass use

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ABSTRACT. In this study, five ecotypes of Bermuda grass (hereafter referred to as Kudat, Sipitang, Tawau, Papar and Beaufort) were evaluated for turfgrass potential. In general trait assessment, the Tawau ecotype was found to be darker green, and had shorter leaf and internodes lengths, while the Beaufort ecotype had shorter shoot length, and the Sipitang ecotype had a higher shoot number. In salt treatment, the Beaufort ecotype (second, Sipitang ecotype) had higher shoot dry weight and lower tissue death. Sipitang ecotype (second, Beaufort ecotype) had higher shoot fresh weight. All ecotypes had similar clipping yield and root fresh weight. In mowing treatment, the Sipitang ecotype (second, Tawau and Papar ecotypes) had higher shoot number. All ecotypes had similar leaf width, root fresh weight and shoot dry weight. In fertilizer treatment, the Sipitang ecotype (second, Kudat ecotype) had higher clipping yield and shoot number. It also had (second, Beaufort ecotype) higher shoot fresh weight and shoot dry weight. All ecotypes had similar root fresh weight. Overall, the results suggested that the Sipitang ecotype is the best among the ecotypes, as it has high shoot number, good environmental stress tolerance and low fertilizer requirement. The Tawau and Beaufort ecotypes are other choices. The Sipitang ecotype, however, could not match the quality of Tifdwarf, a commercial turfgrass used in golf greens. Hence, the good traits of the ecotype indicate that it has other functions other than being used in golf greens. A further study is recommended to test the functional qualities of the Sipitang ecotype to narrow down the practical usage of this ecotype.

Keywords: Bermuda grass, turfgrass potential, salinity, mowing, NPK, Sabah Malaysia.

INTRODUCTION

Tifgreen, Tifway and Tifdwarf are three of the popular cultivars of Bermuda grass used in golf courses and high quality turfs in Malaysia. Tifgreen comes from a cross between *Cynodon dactylon* and *C. transvaalensis* Burtt-Davy, Tifway comes from a natural hybrid of those two Cynodons and Tifdwarf comes from a natural mutant of Tifgreen (Burton, 1991; Burton, 1966a; Burton, 1966b). Tifgreen comes from an artificial process, and Tifway and Tifdwarf from natural process, but all have excellent traits as turfgrasses. Brosnan and Deputy (2008) and Samples and Sorochan (2007) have summarised the good traits of these cultivars as Tifgreen has dark green colour, can tolerate drought well, can compete against weeds and will recover quickly from pest attacks. Tifway shares many good traits with Tifgreen and is nitrogen efficient, but it is less tolerant to drought and has stiffer leaves in comparison to Tifgreen. Tifdwarf shares most good traits with Tifgreen plus has significantly minute leaves, shorter stems and shorter internodes, and it is nitrogen efficient too. Tifway and Tifdwarf demonstrate that excellent turfgrasses exist in the natural habitat.

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Common Bermuda grass cultivars come from careful selection of *C. dactylon* ecotypes (Martin *et al.*, 2007). The target is ecotypes with commercial turfgrass traits. Hybrid Bermuda grass cultivars come from interspecific crosses between *Cynodon* species either through a natural process or human assistance. Not all hybrids have desirable traits for turfgrass use; most commercial hybrids have been preselected before being traded (O'Brien, 2012). Artificial mutation has also been practiced lately to produce desirable quality turfgrass (Stephens, 2009). Bermuda grass has many cultivars and varieties traded under various names around the world. The official number has never been meticulously published, not only because many common cultivars are protected by patent, or not officially published, but also new important ecotypes are still reported worldwide. Bermuda grass ecotypes are popular as parent material for turfgrass development, as the ecotypes are known to have an excellent physiological adaptation to harsh conditions such as saline and dry areas (Nadeem *et al.*, 2012; Zhou *et al.*, 2009). Such traits can make lawn maintenance and management inexpensive (Mintenko *et al.*, 2002; Minteko & Smith, 1999; Minteko & Smith, 1998). Bermuda grass is also reported to have medicinal, livestock feed and biofuel prospects (Syahriel *et al.*, 2012; Albert-Baskar & Ignacimuthu, 2010; Sadki *et al.*, 2010; Singh *et al.*, 2007; Wu, 2011; Muir *et al.*, 2010).

Suitability of grass for turfgrass use is evaluated based on visual and functional qualities (Turgeon, 2008). The evaluation can start either way, but usually visual qualities are carried out first, as these do not require long-term study. The common qualities observed are density, colour, growth habit, texture, uniformity and smoothness (Turgeon, 2008; Romani *et al.*, 2004; Leto *et al.*, 2004). These observations are then supplemented with simple physiological tests such as salt, mowing, drought and wear tolerances, and fertilizer response (Han & Huckabay, 2008). The main purpose is to establish a foundation to select one or two grasses for future functional quality tests. Visual qualities are actually founded on functional qualities. Turgeon (2008) and Emmons (2000) have outlined the requirements of turfgrass visual qualities. High density (dense) is the requirement for density, as the fundamental function of grass is to cover the soil. In field sports, high density is required not only for covering the soil but also to form a cushion to reduce injury to players as well as to provide a smooth platform for sports activities. Dark green is the requirement for colour, as grass should not only cover the soil but also provide an aesthetically attractive and soft colour such as green. In addition, green is a colour of chlorophyll and thus it indicates chlorophyll concentration and grass health (Mangiafico & Guillard, 2005). Prostrate is the requirement for growth habit, as prostrate grass can be maintained at lower mowing height and in addition, the grass can spread faster as the mature shoots are in contact with the ground and thus, the nodes could easily root. Fine texture is the requirement for texture to permit high-speed ball movement and to create a nice feeling for feet, depending on turf field usage and personal preference (Han & Huckabay, 2008). Narrow leaves allow for fine-texture turfgrass. For uniformity and smoothness, the requirements are for shoots of the grass to have the same shape, size and orientation. The latter are not only for aesthetic reasons but also to increase rigidity and resiliency of the grass to endure compaction or to support golf balls (Turgeon, 2008). The aforementioned standards are the requirements for an ideal turf field. In some cases, not all of these standards are required. In general recreational areas, for instance, only standards associated with density, colour and growth habit are required. Visual and functional qualities that the grass should meet depend on how people use the area where grass is planted.

In the present study, a few Bermuda grass ecotypes in Sabah were collected and subjected to basic quality assessments to evaluate the turfgrass potential of the ecotypes. The main objective was to isolate one ecotype that could be subjected for further study to produce a commercial turfgrass for local home lawn beautification. This is a pioneering study on the exploitation of the abundant Bermuda grass population in Sabah, and such a study is still lacking in this region.

METHODOLOGY

The experiment was conducted at an open area in the School of Sustainable Agriculture, Universiti Malaysia Sabah (Sandakan Campus) from April to August 2012. Ecotypes of *C. dactylon* were collected from the roadside at several regions in Sabah. Grassy areas along the roads to Kudat, Papar, Beaufort, Sipitang and Tawau were inspected every one to five kilometers and any *C. dactylon* ecotype found was collected in the form of 1 x 1 sq. ft. sod. Only pure sod was collected; contaminant weeds or other grasses were removed. Each ecotype was verified in the laboratory through careful observation on its leaf vernation, ligule, auricle, leaf tip, leaf upper surface, leaf under surface, mid-rib, collar leaf blade, leaf texture, growth habit, leaf margin and leaf sheath. Only five ecotypes were finally confirmed. For easy referencing, the ecotype was named based on the nearest township where it was collected. Tifdwarf was obtained from the collection of turfgrasses of the School of Sustainable Agriculture and used as comparison. Sods of the ecotypes and the Tifdwarf were reared in stock trays of 33 x 25 x 8.5 cm^3. The grasses were maintained at same inputs until established fully. All were watered twice a day, early in the morning and the late evening, except on rainy days. Humic organic compound fertilizer (NPK13-6-8) at a rate of 2.06 g N per tray was applied every 15 days. Weeds growing in the trays were removed daily using hands. Dimethoate was applied at a rate of 1.0 mL to 1 L of water to control mealybugs. Sprigs from these stocks were used for the experiment.

Media preparation and planting

Media preparation and planting were carried out to attain a Completely Randomized Design experiment with three treatments (Sodium Chloride, mowing height and nitrogen fertilizer) of which each had four levels (0, 7500, 12800 and 18500 mgL^{-1}NaCl; 1.0, 2.0, 3.0, and 4.0 cm mowing height; and 0.06, 0.09, 0.13 and 0.17 g N of NPK13-6-8 per month per cell) and five replicates per treatment level. Sixty six-celled-germination trays of 12 in (length) x 8 in (width) x 4 in (height) size with each cell having a three-inch diameter were used. Sand and loamy clay was mixed at a 4:1 ratio and each cell was filled with 220 grammes of the media. Sprigs were harvested from the main stocks of ecotypes and Tifdwarf. Only healthy sprigs were collected, that is, had excellent physical appearance, disease symptom free, pure green leaves and 10 to 20 cm long stolons. All sprigs were soaked in water overnight before being transplanted into trays to avoid transplanting shock. Each cell received five sprigs of one ecotype. Each sprig had two internodes with each node featuring one emerging tiller and 2-3 young roots. All sprigs were planted at a 2 cm distance from one another. Tifdwarf was also planted in one cell of every tray. The trays were left under the shade for a week before being relocated to open area to receive full sun light. The ecotypes and the Tifdwarf were reared for two months at same inputs. All replicates were watered twice a day, early in the morning and in the late evening, except during rainy days. Fertilizer was applied every 15 days using humic organic compound fertilizer NPK13-6-8 at a rate of 0.17 g N per cell. Weeds growing in the cell (or between trays) were removed daily using hands. Dimethoate was applied at a rate of 1.0 mL to 1 L of water to control mealybugs. Growth data were recorded at week 4 and 8: leaf width, leaf length, internode length, number of shoot, leaf colour and shoot length. After week 8, the grasses were subjected to salt, mowing and fertilizer treatments.

Salt treatment

Common *C. dactylon* underwent 50% weight reduction at a salinity range of 25.9 dSm^{-1} to 29.7 dSm^{-1} (Kamal-Uddin *et al.*,2010). Tifdwarf underwent 50% weight reduction at 12 dSm^{-1} (Barley *et al.*, 2009). Hence, in this study, concentrations of NaCl were selected between the highest and lowest dSm^{-1} of those previous studies. The selected concentrations were 11.7 dSm^{-1}, 20 dSm^{-1} and 28.9 dSm^{-1}. As the salt was added as milligram per one Liter of water (mgL^{-1}), the equivalent conversions were 7500 mgL^{-1}, 12800 mgL^{-1} and 18500 mgL^{-1}NaCl, respectively. The conversion formula was 'Total dissolved salts (mgL^{-1}) = electrical conductivity (dSm^{-1}) x 640.' No addition of NaCl was the control. NaCl solution was applied on daily basis. Each cell received a quarter volume of NaCl solution so that the solution could reach the root zone. Twice the volume of water was poured on alternate days to maintain salt concentration uniformity associated with leaching and drainage of excess water in the cells (Mane *et al.*, 2011). The experimental units received other basic requirements such as fertilizer NPK13-6-8 at 0.17 g $Nm^{-2}month^{-1}$ per cell. The grasses were cut on a weekly basis to maintain its height at 4 cm. Growth data were recorded at week 4 and 8: clipping yield, leaf firing, root fresh weight, shoot fresh weight and shoot dry weight.

Mowing treatment

Four mowing heights were selected in correspondence with the common height applied in general lawn and recreational area maintenance: 4.0 cm (control), 3.0 cm, 2.0 cm and 1.0 cm. The grasses were cut on weekly basis using scissors. Two pairs of wooden sticks with scales were clipped on the tray. Rubber bands were fastened on the sticks corresponding to the desired mowing height and used as reference level to cut the grass. The experimental units were still supplied with other basic requirements such as NPK13-6-8 fertilizer at 0.17 g $Nm^{-2}month^{-1}$ per cell, and water twice daily. The cells were sand top-dressed twice a month to ensure loss of medium (by rain splash) was replaced, so that every cell could have the same level of medium with the tray's surface, as the surface was used as a reference point to measure cutting height. Growth data were recorded at week 4 and 8: number of shoot, leaf width, root fresh weight, shoot fresh weight and shoot dry weight.

Fertilizer treatment

NPK13-6-8 fertilizer was used. Emmons (2000) stated that high quality *C. dactylon* turfgrass required as much as 6.5 nitrogen per metre square per month ($Nm^{-2}month^{-1}$). However, the lowest rate can be as low as 2.44 g $Nm^{-2}month^{-1}$ (Duble, 1996). Thus, the N rates selected in this study were within that range: 6.5 g (control), 4.8 g, 3.2 g, and 2.4 g $Nm^{-2}month^{-1}$. Equivalent conversions for per cell application were 0.17, 0.13, 0.09 and 0.06 g N per month, respectively. Formula used for the conversion was 'Fertilizer rate = 100/13 x (grams of $Nm^{-2}month^{-1}$) x cell area in m^2.' Cell area was around 34.25 cm^2 (or 0.003425 m^2). All grasses were maintained at 4 cm height (cut on weekly basis) and watered twice a day. Growth data were recorded at week 4 and 8: clipping yield, root fresh weight, shoot fresh weight and shoot dry weight.

Measurements of growth parameters

Parameters (and standards) evaluated were colour (dark green is better), leaf width (narrower is better), internodes length, leaf length, shoot length (for the latter three, shorter is better), tissue death or leaf firing (lower is better), shoot number, clipping yield, root fresh weight, shoot fresh weight and shoot dry weight (for these five, higher is better). Leaf colour was measured using a Konica Minolta Cr-10 Model colour reader. The reading was taken on mature leaves in the afternoon (12 pm to 1pm) during high light intensity (Mangiafico & Guillard, 2005). Poor leaves (chlorotic or brownish) were avoided to obtain the true genetic colour of the grasses. Only hue value was recorded, as it indicates true colour (red, yellow, green and blue, etc.); it is the angle of the plane dimension of the three dimensions of colour expression. It starts at red (0°) to yellow (90°), green (180°), blue (270°), and red again (360°); but colour is more complex than this definition. The complex colour of 'green' lies somewhere between 126°-234°, which means any reading above 234° is considered dark green as it moves toward blue-green and blue at 270° (Konica Minolta, 2007). Leaf width was measured using caliper in millimeter as the widest part of the leaf blade. Three healthy matured leaves (well opened but not old) were measured per cell. Internode length was measured in centimeter as the distance between two nodes of mature stolon. Leaf length was measured in centimeter as the length from leaf tip to the leaf base (leaf collar).

Shoot length was measured as the length from the soil surface to the tips of the shoot. Tissue death or leaf firing was measured as the number of chlorotic leaves in relative to non-chlorotic leaves expressed in percentage (Lee *et al.*, 2004). Shoot number was measured as a count of tillers per cell area. Clipping yield was measured as the weight of the clips. Two wooden sticks were fixed in parallel on the right and left sides of the tray and rubber band was fastened on the sticks to indicate the level at which the clipping was carried out. The shoots' top-growth was cut and every clip collected, placed into a paper bag, oven dried at 60°C for 24 hours (Liu and Kobayashi, 2002) and measured for weight using electronic balance. Root fresh weight was measured using non-destructive method in that the sod (consist of medium, roots, and shoots) weight per cell subtracted the medium weight per cell (all cells received 220 g of media) and the total shoot fresh weight per cell. Shoot fresh weight was measured as the average weight of three fresh mature tillers with similar leaf number per cell; the tillers were cut deeper into the grass crown, approximately 1.0 cm into the soil, to avoid any part being left behind; and the average weight was multiplied with the number of shoots in the cell to obtain the total shoot fresh weight per cell. Shoot dry weight was measured as the dry weight of the collected tillers for shoot fresh weight measurement; the tillers were oven dried at 70°C for 48 hours, weighed and the average was multiplied with the number of shoots in the cell to obtain total shoot dry weight per cell.

Data analysis

Measurements were carried out in week 4 and 8. However, as most ecotypes managed to survive beyond week 4 of the treatments, only results of week 8 were presented. Growth data obtained were analysed using SPSS® Version 18(Pallant, 2011). Two-way ANOVA was performed to infer the treatment effects (responses of the ecotypes and the Tifdwarf to the treatments). Data normality was evaluated using Levene Test. Leaf firing data (percentage data) were transformed using arcsine transformation prior to ANOVA, but the new set of values obtained were re-transformed to percentage for graph plotting purposes. Shoot number was not normally distributed, which was due to the high difference between shoot number of the ecotypes and the Tifdwarf. Hence, the data were subjected to Log10 transformation prior to ANOVA and again, the new set of values obtained were re-transformed into its original unit (count of number) for graph plotting purposes. Standard errors of the means were also calculated and used to evaluate differences between means of one to another ecotype in particular treatment level.

RESULTS

General descriptions on ecology and botany of the ecotypes

The ecotypes were part of the results of this study thus providing general but relevant description on the ecology of the collection sites and the botany of the ecotypes important to support the evaluation process to assess turfgrass potential of each ecotype. The Kudat ecotype was collected at the roadside adjacent to an oil palm plantation. The soil was found to be mainly residual sand and gravel used for road construction. Soil erosion from the oil palm plantation caused clay to mix with the sand, allowing a natural formation of water absorbing substrate. The soil thus retains excess water. It was found that drivers occasionally park vehicles on the collection site, which indirectly means that the ecotype is tolerant to compaction. The Papar ecotype was collected at the roadside in an adjacent to disturbed forest. The soil was also mainly residual sand and gravel used for the road construction. There was no soil erosion from the forest and since clay was absent in the soil, it was found to drain water better. The Papar ecotype is also assumed to be tolerant to compaction, as motorists sometimes park vehicles on the collection site. The Beaufort ecotype was collected adjacent to an under reconstruction road. The upper layer was scrapped off, leaving only compacted sandy-loam soil for the grass. The soil was slightly dry, as rainwater could run off easily from the soil surface. The Sipitang ecotype was collected in front of a bus stop. The soil was a thick layer of sand, which perhaps had been placed to allow water in the surrounding area of the bus stop to drain out. This ecotype is also assumed to be highly tolerant to compaction and perhaps salt, as the collection site is not far from the sea. The Tawau ecotype was collected in front of a bus stop adjacent to an oil palm plantation. The soil was a compact mixture of sand and clay. It was dry for long time, as its surface repelled water rather than absorbed it. Generally, in term of harshness (high to low), the collection sites can be arranged as Tawau, Beaufort, Sipitang, Kudat and Papar ecotypes. All ecotypes, however, grew well at the collection sites, indicating that every ecotype has adapted to the respective sites.

All ecotypes had similar botanical characteristic, except for leaf vernation and growth habit. All ecotypes had a-fringe-of-hair ligule, no auricle, pointed and hairy leaf-tip, hairless leaf's upper surface, hairless and shiny leaf's under surface, present of mid-rib, narrow continuous collar, distinct vein, soft and pliable leaf blade, smooth leaf margin, glabrous sheath, and fine to medium leaf texture (1.5 mm to 3.0 mm). However, while the rest had folded, the Kudat ecotype had rolled leaf vernation. The Sipitang ecotype had semi-prostrate growth habit, Beaufort ecotype semi-upright, and the rest upright. The Kudat ecotype was considered to have upright growth habit, as its tillers grew at 90 degrees to the basal stolon nodes. One tiller was noticed growing at every node. The Sipitang ecotype had semi-prostrate growth habit, as its tiller grew at almost 45degrees to the basal stolon node. Two tillers (sometimes one or three) were noticed growing at every node. This character indicates that the Sipitang ecotype has higher tillering rate. The Tawau ecotype had similar growth habit as the Kudat ecotype. One or two tillers grew at every node. The second tiller, however, was found to grow much later, only after the first one had grown into extended length. Just as the Tawau ecotype, the Papar ecotype had an upright growth habit and late secondary tillering. Two tillers emerged at every node. The Beaufort ecotype had semi-upright growth habit, as its tillers emerged at 45 degrees to the basal stolon node. Alternately, the tiller grew on the left or right of the node. One rather than two tiller per node was frequent.

Growth before treatments

Each ecotype had similar leaf width, but wider than that of the Tifdwarf (F=13.048, df=5, 294, p=0.000; Table 1). All ecotypes had similar colour too, although less green than the Tifdwarf (F=87.973, df=5, 294, p=0.000; Table 1). The Beaufort, Sipitang and Kudat ecotypes had longer leaf length in relative to Papar and Tawau ecotypes and Tifdwarf (F=87.973, df=5,294, p=0.000). The ecotypes can be arranged based on the leaf length as Beaufort (2.4 cm long), Sipitang (2.4) and Kudat (2.3) >Papar (1.8) and Tawau (1.6) >Tifdwarf (1.4). Beaufort ecotype had longer internode length in relative to Sipitang, Papar, Tawau and Kudat ecotypes and Tifdwarf (F=25.947, df=5, 294, p=0.000). The ecotypes can be arranged based on the internode length as Beaufort (3.2 cm long) >Sipitang (2.9) and Papar (2.8) >Tawau (2.5), Kudat (2.5) and Tifdwarf (1.4). The Kudat and Tawau ecotypes had longer shoot length in relative to the Sipitang, Papar and Beaufort ecotypes and Tifdwarf (F=5.504, df=5,294, p=0.000); the shoot length arrangement was Tawau (27.4 cm long) and Kudat (27.2) >Papar (26.0) >Sipitang (24.4) and Tifdwarf (23.4) > Beaufort (21.9). Among the ecotypes, Sipitang had the highest number of shoot per cell area (7.8 x 4.4 = 7.5 x 4.5 = 34 cm sq.), but all ecotypes had fewer number of shootsin comparison to Tifdwarf (F=63.018, df=5,294, p=0.000). Based on the number of shoot per area, the ecotypes can be arranged as Tifdwarf (29 shoots) >Sipitang (21) > Beaufort (19) and Kudat (18) >Papar (16) and Tawau (15).

Effects of salt

Each ecotype and the Tifdwarf had similar clipping yield and root fresh weight means irrespective of salt concentration (F=0.997, df=5, p=0.424, Figure 1; and F=1.538, df=5, p=0.185, respectively). Root fresh weight mean was 62.19, 59.62, 58.87, 57.91, 56.68 and 66.11 g for Beaufort, Tawau, Sipitang, Papar and Kudat ecotypes and Tifdwarf, respectively.

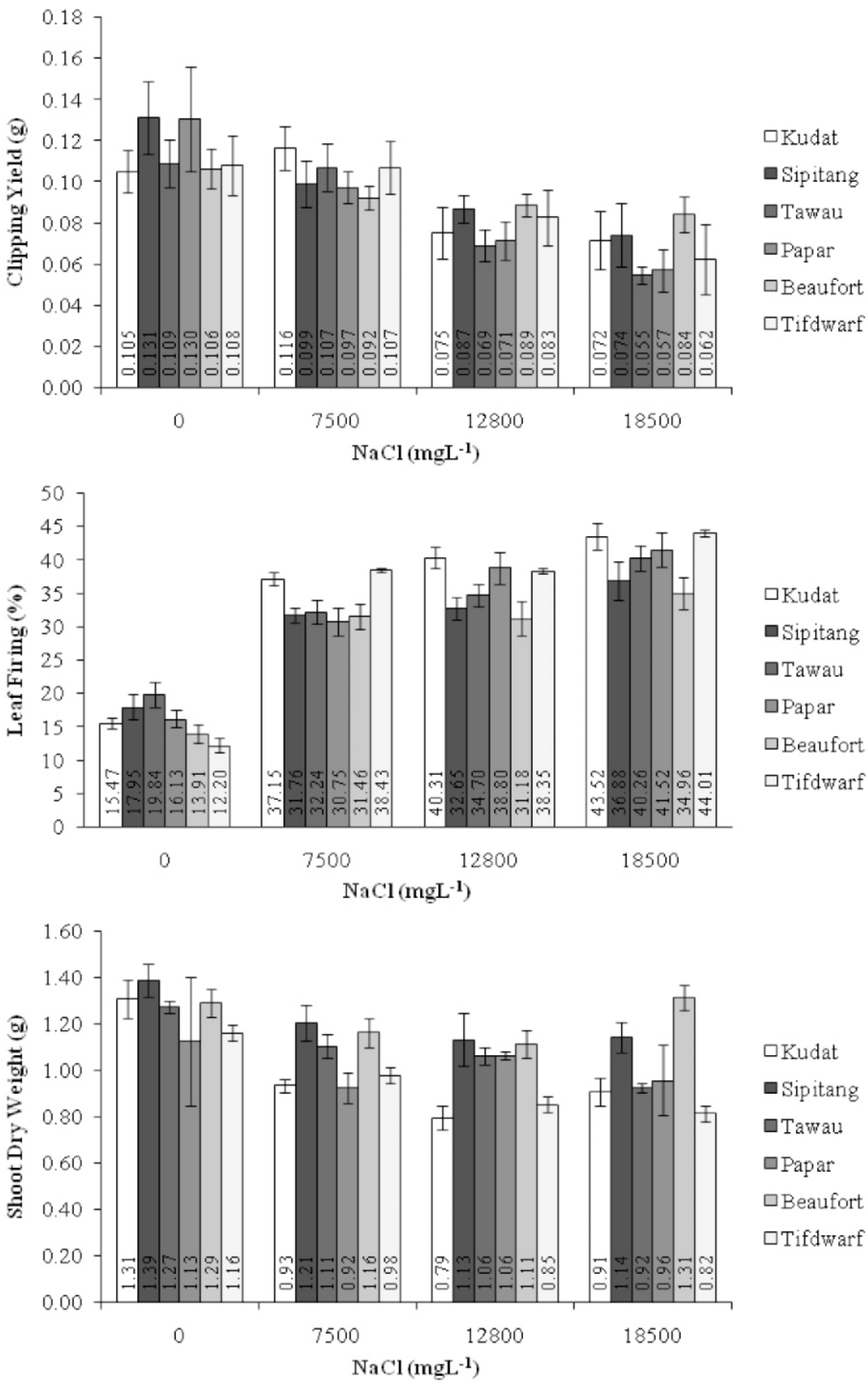

Figure 1. Clipping yield, tissue death (leaf firing) and shoot dry weight means of *C. dactylon* ecotypes under 0, 7500, 12800 and 18500 mgL^{-1} salt addition. (Small bars represent standard error of the means).

Kudat, Tawau and Papar ecotypes and Tifdwarf suffered higher tissue death in relative to Sipitang and Beaufort ecotypes (F=3.615, df=5, p=0.005, Figure 1). Beaufort and Sipitang ecotypes had higher shoot dry weight and shoot fresh weight means followed by Papar, Tawau and Kudat ecotypes, and the latter by Tifdwarf (F=7.142, df=5, p=0.000, Figure 1; and F=22.438, df=5, p=0.000, respectively). Shoot fresh weight mean was 2.95, 2.75, 2.63, 2.46, 2.23 and 1.99 g for Sipitang, Beaufort, Tawau, Papar and Kudat ecotypes and Tifdwarf, respectively. Two-way ANOVA suggested that clipping yield mean (F=1.310, df=15, p=0.211), tissue death mean (F=1.406, df=15, p=0.160), root fresh weight mean (F=0.640, df=15, p=0.835), shoot fresh weight mean (F=1.357, df=15, p=0.185) and shoot dry weight mean (cellulose, food and non-volatile secondary metabolite deposit: F=1.080, df=15, p=0.385) of the grasses did not have specific interaction with salt concentration. Irrespective of ecotypes and the Tifdwarf, total clipping yield and shoot dry weight means of all grasses decreased with increasing salt concentration (F=16.748, df=3, p=0.000 and F=11.431, df=3, p=0.000, Figure 1). Total shoot fresh weight means also decreased with increasing salt concentration (F=79.278, df=3, p=0.000); it was 3.30, 2.36, 2.14 and 2.21 g for 0, 7500, 12800 and 18500 mgL^{-1}NaCl, respectively. However, total tissue death (leaf firing) and root fresh weight means increased with increasing salt concentration (F=119.219, df=3, p=0.000, Figure 1; and F=5.775, df=3, p=0.001). Root fresh weight associated with 0, 7500, 12800 and 18500 mgL^{-1}NaCl was 52.25, 62.12, 62.24 and 64.31 g, respectively.

Effects of mowing

Sipitang, Tawau and Papar ecotypes had higher shoot number mean in relative to Kudat and Tawau ecotypes, but all ecotypes had lower shoot number compared to Tifdwarf (F=195.362, df=5, p=0.000, Figure 2). Leaf width mean of the ecotypes was similar but much wider than that of the Tifdwarf (F=11.216, df=5, p=0.000, Figure 2). Root fresh and shoot dry weight means were similar across the ecotypes and Tifdwarf (F=0.986, df=3, p=0.403; and F=1.545, df=5, p=0.183, respectively), but shoot fresh weight mean were not (F=11.008, df=5, p=0.000). The overall shoot fresh weight mean was 2.22, 2.15, 2.12, 2.03, 1.71 and 1.84 g for Sipitang, Papar, Tawau, Beaufort and Kudat ecotypes and Tifdwarf, respectively. If the comparison was limited at 1.0 cm mowing height, the Papar ecotype had higher shoot fresh weight, followed by Tawau and Sipitang ecotypes, and later by the Beaufort, Tifdwarf and Kudat ecotypes. At that mowing height, Sipitang, Tawau and Papar ecotypes had higher shoot dry weight mean in relative to Kudat and Beaufort ecotypes and Tifdwarf (standard error mean comparison; Figure 2). Again at that mowing height, Tifdwarf had higher root fresh weight, followed by Tawau and Sipitang ecotypes, and the latter by Papar, Beaufort and Kudat ecotypes; respectively, root fresh weight mean of the grasses was 52.87, 47.72, 47.23, 40.97, 36.92 and 36.11 %. Two-way ANOVA suggested that shoot number mean (F=1.353, df=15, p=0.187), leaf width mean (F = 0.950, df=15, p=0.509), root fresh weight mean (F=1.324, df=15, p=0.203) and shoot dry weight mean (F=1.153, df=15, p=0.322) of the grasses did not have specific interaction with mowing height. However, shoot fresh weight mean did have an interaction with mowing height (F=2.267, df=15, p=0.009). Irrespective of ecotypes and the Tifdwarf, total shoot number mean of all grasses was higher at higher mowing height (F=4.102, df=3, p=0.000, Figure 2). This trend was also applicable to leaf width (wider, F=0.964, df=3, p=0.000, Figure 2), shoot dry weight (heavier, F=195.958, df=3, p=0.000, Figure 2) and shoot fresh weight (heavier, F=479.527, df=3, p=0.000). Total shoot fresh weight mean associated with 1.0, 2.0, 3.0 and 4.0 cm mowing heights was 0.85, 1.52, 2.37 and 3.30 g, respectively. Total root fresh weight mean, however, was similar across the mowing heights (F=0.986, df=3, p=0.403). Total root fresh weight mean associated with 1.0, 2.0, 3.0 and 4.0 cm mowing heights was 43.64, 44.60, 46.95, and 41.99 g, respectively.

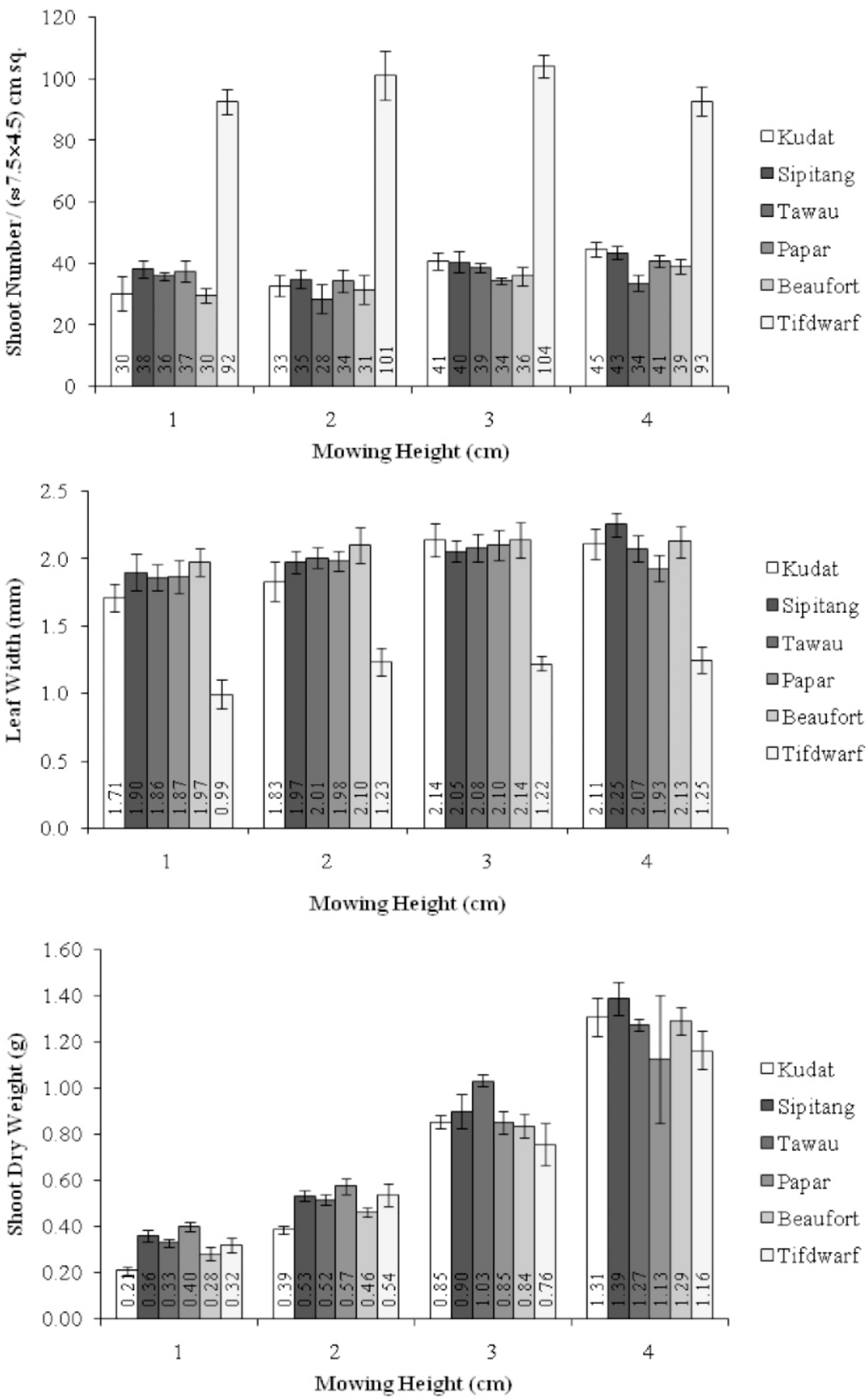

Figure 2. Number of shoot, leaf width and shoot dry weight means of *C. dactylon* ecotypes under 1.0, 2.0, 3.0, and 4.0 cm mowing height. (Small bars represent standard error of the means).

Effects of fertilizer (NPK13-6-8)

Clipping yields of the ecotypes especially Sipitang and Kudat ecotypes were higher than that of Tifdwarf (F=6.480, df=5, p=0.000, Figure 3). However, Tifdwarf had higher number of shoots than the ecotypes (F=196.309, df=5, p=0.000, Figure 3). Sipitang ecotype had higher shoot dry weight and shoot fresh weight means, followed by the Beaufort, Tawau, Papar and Kudat ecotypes, and Tifdwarf (F=14.640, df=5, p=0.000, Figure 3; and F=50.622, df=5, p=0.000, respectively). Overall shoot fresh weight mean was 3.28, 2.84, 2.64, 2.61, 2.40 and 1.95 g for Sipitang, Beaufort, Tawau, Papar and Kudat ecotypes and Tifdwarf, respectively. Root fresh weight mean, however, was similar across the ecotypes and Tifdwarf (F=0.801, df=5, p=0.552). Overall root fresh weight mean was 50.15, 46.25, 44.26, 45.29, 43.63 and 51.19 for Papar, Beaufort, Sipitang, Tawau and Kudat ecotypes and Tifdwarf. Two-way ANOVA suggested that clipping yield (F=0.610, df=15, p=0.807), shoot number (F=0.853, df=15, p=0.617) and root fresh weight (F=0.589, df=15, p=0.877) of the grasses did not have specific interaction with fertilizer concentration. Even so, shoot fresh weight (F=3.371, df=15, p=0.000) and shoot dry weight (F=1.850, df=15, p=0.038) did have an interaction with fertilizer concentration. Irrespective of ecotypes and the Tifdwarf, total clipping yield (F=11.766, df=3, p=0.000) and total shoot number means (F=39.200, df=3, p=0.000, Figure 3) of all grasses increased with increasing fertilizer concentration. This trend was also applicable to total shoot dry weight (F=52.984, df=3, p=0.000) and total shoot fresh weight means (F=139.347, df=3, p=0.000). The latter was 1.94, 2.34, 2.89 and 3.30 g for 0.06, 0.09, 0.13 and 0.17 g $Nm^{-2}month^{-1}$ of NPK13-6-8, respectively. Total root fresh weight mean, however, was similar across the fertilizer treatment (F=2.200, df=3, p=0.093); it was 43.53, 43.28, 43.13 and 52.25 g for 0.06, 0.09, 0.13 and 0.17 g $Nm^{-2}month^{-1}$ of NPK13-6-8, respectively.

DISCUSSION

General traits

The Tawau ecotype leads three out of the six traits evaluated. Papar, Beaufort and Sipitang ecotypes lead the other three traits, respectively. In term of general traits associated with leaf width, the Papar ecotype is better in relative to the other ecotypes, although not as good as Tifdwarf (2.1 vs. 1.1 mm for Tifdwarf). Leaf width of Papar ecotype was closely similar to that of the 13 and 16 ecotypes reported by Leto *et al.* (2004) for Italian Bermuda grass. For colour, Tifdwarf is better. Tawau ecotype was almost dark green, but not as green as Tifdwarf (203 hue index vs. 250 for Tifdwarf). For leaf length, Tawau ecotype is better in relative to the other ecotypes and almost comparable to Tifdwarf (1.6 vs. 1.4 cm for Tifdwarf). For internodes length, the Tawau ecotype (second, Kudat ecotype) is better in comparison to other ecotypes but not as good as Tifdwarf (2.5 vs. 1.4 cm for Tifdwarf). For shoot length, the Beaufort ecotype is better in comparison to the rest including Tifdwarf (21.9 vs. 23.4 cm for Tifdwarf). For shoot number, the Sipitang ecotype (second, Beaufort ecotype) is better when compared to the other ecotypes but not as good as Tifdwarf (21 vs. 29 for Tifdwarf). Based on these evaluations, Tawau ecotype has the most potential while the Kudat ecotype has the least potential as turfgrass. In addition, Tawau ecotype has beautiful appearance. However, lawns that receive high traffic need turfgrass with a high shoot number, good rooting capability, and good recovery, which is associated with turfgrass of prostrate or semi-prostrate growth habit. Priority is given to high density as the basic function of grass is to cover the ground (Turgeon, 2008). Sipitang and Beaufort ecotypes are better in that respect.

General responses to salinity, mowing and fertilization

Salt

It is expected that total clipping yield, shoot dry weight and shoot fresh weight decrease with

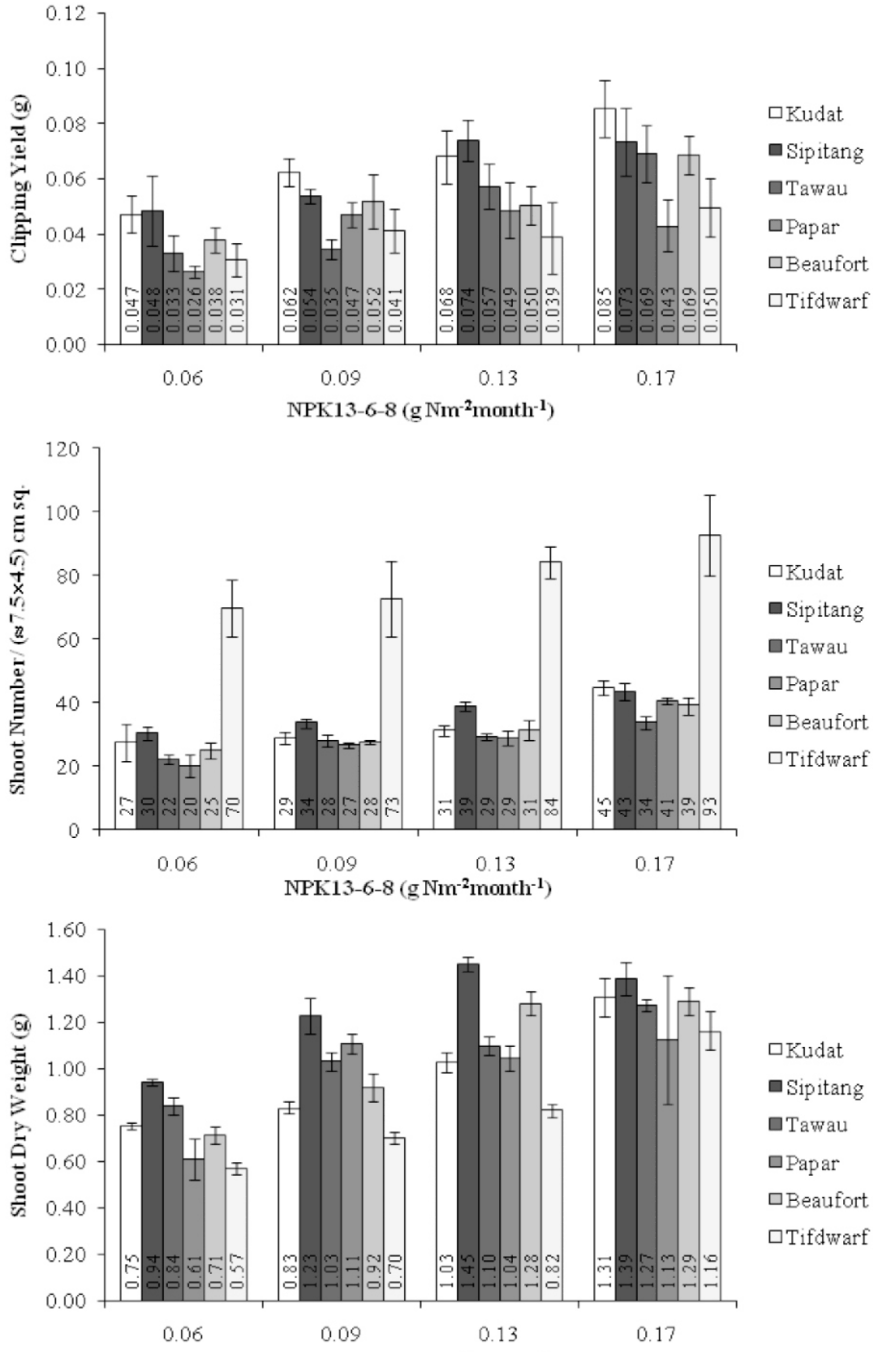

Figure 3. Clipping yield, number of shoot and shoot dry weight means of *C. dactylon* ecotypes under 0.06, 0.09, 0.13, and 0.17 g $Nm^{-2}month^{-1}$ addition of NPK13-6-8. (Small bars represent standard error of the means).

increasing salt concentration. It is also expected that total tissue death (leaf firing) increases with increasing salt concentration. Salt desiccates plant and disorients its nutrient uptake. It causes roots to experience negative osmosis, distorts root nutrient uptake and impedes plant growth (Hajibagheri *et al.*, 1989). Salt accumulated in mature leaves damages leaf tissues and decreases leaf photosynthetic activity. Negative osmosis causes mesophyll turgidity loss and partial stomata opening, reducing total leaf carbon dioxide assimilation per day (Hussain *et al.*, 2012). In saline soil, plants will die when new leaf formation cannot match leaf death or produce sufficient energy for plants (Munns & Termaat, 1986). High salt level deteriorates plant health. However, in this study, it is not expected that root fresh weight will increase with rising salt concentration. High salt concentration increases root respiration, causing the plant to assimilate more carbohydrates to secrete ions and to repair damaged tissues. Excessive salt decreases overall root growth (Hussain *et al.*, 2012; Maathuis & Amtmann, 1999), and in severe conditions, the roots will die. An exception is Bermuda grass that might require sodium or chloride during its early development (Munns and Termaat, 1986). Bermuda grass's root mass increases as salt concentration rises until it reaches a peak before starts to decline (Dudeck *et al.*, 1983).That scenario may have happened in this study, but root mass have not had reached the peak.

Clipping yield, tissue death, root fresh weight, shoot fresh weight and shoot dry weight of the ecotypes and Tifdwarf did not have specific interactions with salt concentration. These results could indirectly prove Munns & Termaat's (1986) assumption. Bermuda grass does not have absolute negative relationship with salt. It uses salt at one time and not at another time. The relationship is random and not specific. Each ecotype has a different strategy to deal with salt, depending on salt concentration, time and space. Turfgrass salinity tolerance is a result of multi-interactions between gene expression, salinity tolerance mechanism, environmental, edaphic and plant factors (Marcum, 2006; Carrow & Duncan, 1999).

Mowing

It is expected that mowing increases shoot number. Mowing reduces grass biomass and decreases photosynthetic activity. Hence, grass has to produce more tillers to maintain its metabolic activity and thus increases in density (Turgeon, 2008). High mowing height means low biomass removal. Thus, total shoot number, leaf width, shoot fresh weight and shoot dry weight decrease with lowering mowing height. If biomass removal is excessive, grass cannot generate sufficient energy to grow and to produce tillers. Mowing below the lowest limit will kill the grass (Emmons, 2000). In this study, the 1.0 cm mowing height was not the lowest limit. Most of the ecotypes were still thriving at that mowing height especially the Sipitang ecotype. That ecotype had a semi-prostrate growth habit, which was an advantage because many of its stolons were prostrating on the ground and were not affected much at 1.0 cm mowing height.

Shoot number, leaf width, root fresh weight and shoot dry weight of the ecotypes and Tifdwarf did not have specific interaction with mowing height. These results indicate that no specific amount of shoot, width of leaf, fresh weight of root and dry weight of shoot could be associated with specific mowing height. Shoot fresh weight, however, did have an interaction with mowing height. The latter means that mowing regulates shoot water content. Plant maintains a particular amount of water in the tissues for metabolic activity, and it adjusts this limit accordingly to amount of water used for photosynthesis or loss through transpiration (Xu & Hsiao, 2004). Thus, lowering mowing height means decreasing water capacity retention of the grass. The lowest capacity depends on the size of the grass. Having small stolon diameter, short internodes length, and short leaf length means the grass could not retain much water. At different mowing height, shoot fresh weight is thus expected to be significantly different across the ecotypes and Tifdwarf. Perhaps heat had also affected the results of this study. Crop water stress baselines are indeed quite variable and depending on various factors (Al-Faraj *et al.*, 2001).

Fertilizer

Fertilizer improves plant growth. It is thus expected that total clipping yield, shoot number, shoot fresh weight and shoot dry weight of the ecotypes and Tifdwarf increased with increasing fertilizer concentration. It is also expected that shoot dry weight of the grasses had specific relationship with fertilizer concentration. As fertilizer addition increases, grasses produce more foods and deposit more cellulose on cell walls. However, the relationship between fertilizer concentration and plant growth varies. Plant nutrient utilization is not efficient due to various internal and external factors (May *et al.*, 2009). Only a portion of the fertilizer could be taken up by a plant and of that portion, only a part of it is used for growth (Barton & Colmer, 2006). Hence, a particular weight of clipping, number of shoot or fresh weight of root of the grasses could not be associated with specific concentration of fertilizer. In this study, only shoot fresh weight had specific interaction with fertilizer concentration, and this is because plant nutrient uptake depends on water as its transport medium (Lack & Evans, 2005).

Growth under stressed condition

Which ecotypes perform well at high salt concentration? The results suggested Beaufort, followed by Sipitang ecotype. The Sipitang and Beaufort ecotypes have high freshwater storing capability as suggested by the high shoot fresh weight of these ecotypes in high salt concentration treatment. Both ecotypes originated from coastal areas and thus are used to saline soil. Genetic variation and diversity of common Bermuda grass are associated with their geographic origins (Wu *et al.*, 2009), and stress response of turfgrass is inheritability one to another progeny (Schwartz *et al.*, 2009). Roots of salt tolerance Bermuda grass are reported to have efficient osmotic system to avoid negative osmosis in saline soil (Hameed & Ashraf, 2008). Prostrate growth could also increase canopy evapotranspiration resistance rate in grass (Kim & Beard, 1988) and this trait could be an additional advantage for the Sipitang ecotype to control water loss and avoid severe leaf firing.

Which ecotypes perform well at low mowing height? The results suggest Sipitang and followed by the Tawau ecotype. Sipitang ecotype has semi-prostrate growth habit and thus it could retain a few more leaves even at low mowing height. However, it is interesting that the Tawau ecotype could survive well at low mowing height, considering that it has upright growth. The explanation could be that Tawau ecotype has broader leaves (Table 1) and thus it has sufficient leaf area to photosynthesis even only a few leaves left at 1.0 cm mowing height. TifEagle Bermuda grass mowed at 3.2 mm height had 19 % more total non-structural carbohydrate compared with that at 4.7 mm height (Bunnell *et al.*, 2005).

Which ecotypes perform well at low fertilizer addition? The results suggested that Sipitang and followed by Beaufort ecotype. At 0.06 g $Nm^{-2}month^{-1}$ NPK13-6-8 per 35 cm sq., the Sipitang ecotype had higher clipping yield, shoot number, shoot fresh weight and shoot dry weight. The Beaufort ecotype is second best in those traits.

Potential use

The results suggest that Sipitang ecotype has potential to be used as turfgrass. Tawau and Beaufort ecotypes are other choices. Sipitang ecotype has high shoot number, good environmental stress tolerance and low fertilizer requirement. The results also suggest that beautiful grass does not always have good physiological endurance. The Sipitang ecotype, however, could not match Tifdwarf in terms of quality. Even so, some traits favoured the ecotype over Tifdwarf, which means that it has other functions than being used in golf greens. The Sipitang ecotype could be used for turfing of lawns at playgrounds, houses, airfield and the office lawn. Most of these lawns do not directly generate revenue, but require good turfgrass. These lawns need low maintenance but beautiful turfgrass. That function does not fit with Tifdwarf, as high quality turfgrasses are

Table 1. Growth means of C. dactylon ecotypes before treatments.

Growth Parameter	Ecotypes					Control
	Kudat	Sipitang	Tawau	Papar	Beaufort	Tifdwarf
Leaf Width (mm)	2.2[b]	2.3[b]	2.4[b]	2.1[b]	2.3[b]	1.1[a]
Leaf Colour (Hue index)	195[ab]	193[a]	203[ab]	200[ab]	197[ab]	250[b]
Internodes Length (cm)	2.5[bc]	2.9[cd]	2.5[b]	2.8[c]	3.2[d]	1.4[a]
Leaf Length (cm)	2.3[d]	2.4[d]	1.6[b]	1.8[c]	2.4[cd]	1.4[a]
Shoot Length (cm)	27.2[c]	24.4[ab]	27.4[c]	26.0[bc]	21.9[a]	23.4[ab]
Number of Shoot	18[bc]	21[d]	15[a]	16[ab]	19[cd]	29[e]

*Values followed by same letter are not significantly different at *p*=0.05 (Turkey Test).

also high maintenance turfgrasses. The beautiful golf courses in Sabah need on average RM25,243 a month for course maintenance. Their managers spend about RM3,603, RM941, RM2,590, RM6,439, and RM11,670 a month to buy fertilizer, pesticide and machine fuel, and to cover machine operation and machine maintenance costs, respectively (Yiow, 2012). A few golf courses spend more than that average in a month for course maintenance.

Future studies

Commercial prospect of grass as turfgrass depends on its functional qualities (Turgeon, 2008). These are the qualities associated with rigidity, resiliency, elasticity, putting speed, rooting capacity and recuperative capacity as well as density of the turfgrass. The functional qualities of the Sipitang ecotype have to be tested to narrow down the practical usages of this ecotype. It is also recommended that more Bermuda grass ecotypes in more areas throughout of Sabah are collected for their potential and other importance. A few ecotypes of this grass have good antimicrobial activity against both gram-positive and gram-negative pathogens (Syahriel *et al.*, 2012). One has been reported as livestock feed (DVSAI, 2004), but its full potential for that purpose has not yet been well studied. Evaluating the DNA and genetic diversity of the grass is also important to differentiate useful and less useful ecotypes.

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