Evaluation of Morphological and Yield Characteristics of Selected Local Pumpkin Accessions in Sri Lanka

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Abstract- *Pumpkin is a popular vegetable cultivated worldwide for its high nutritional value and health benefits. The lack of locally developed elite germplasms has led farmers in Sri Lanka to adopt imported hybrid varieties. This implies the necessity of strengthening breeding programs for promoting local pumpkin germplasms. Hence, the present study was focused on evaluating seven pumpkin accessions obtained from Plant Genetic Resource Centre, Gannoruwa and to characterize morphologically and to assess their yield potentials. A field experiment was carried out by implementing a randomized complete block design with three replicates. Quantitative morphological traits were analyzed by ANOVA techniques. Accordingly, the vine length at flowering ranged between 2.5 m- 3.9 m ($p<0.05$), the shortest stem was produced by T1 while the longest were observed in T4 and T6. Interestingly, the number of days taken to male and female flowering ranged between 33-36d ($p<0.05$), denoting that all accessions had displayed early flowering character than the commercial pumpkin varieties (55d). At harvest, the highest fruit yield was recorded in accessions Thirunaweli (9.6 kg/plant) while the remainder counterparts had displayed half of the yielding capacity ($p<0.05$). Moreover, the analysis qualitative trait revealed that accession Wellawaya produced distinct ovate leaf shapes and fruits skin color (cream), while in Thirunaweli, had displayed unique cylindrical-shaped fruits. Moreover, Principal component analysis revealed that accessions Thirunaweli had distinct cluster form the remainder germplasms. Hence, based on the results it was found that the overall performance of Thirunaweli and Wellawaya accessions were superior and suggested to introgress with the local crop improvement programs.*

Keywords: Crop improvement program, Pumpkin accessions, Qualitative and quantitative characteristics

I. INTRODUCTION

Pumpkin (*Cucurbita maxima*, 2x = 2n = 40), belongs to Cucurbitaceae family, is an important commercial crop widely cultivated in many tropical and sub-tropical region of the world as vegetable and an ornamental plant (Dhiman *et al*., 2009). Due to its high nutritional value and health benefits, nowadays it has gained a great concern compared to other crops (Yunli *et al*., 2020). Studies on pumpkins have demonstrated their health benefits to human such as reducing blood glucose level and make insulin available in diabetic patients (Caili *et al*., 2006). There are mainly five cultivated *Cucurbita* species around the world *viz; Cucurbita maxima, Cucurbita moschata, Cucurbita pepo, Cucurbita ficifolia* and *Cucurbita mixta* (Naik *et al*., 2015). The former species, *Cucurbita maxima* is considered to be originated and domesticated from South America. Since then, these cucurbits have been associated with human nutrition and culture for more than 12,000 years (Castellanos-Morales, 2019).

In the local context, pumpkin is a popular vegetable in Sri Lanka which is grown during *Maha* and *Yala* seasons all year across the island (DOA, 2020). The major pumpkin growing areas are Mathale, Anuradhapura, Batticoloa, Mahaweli system H, Kurunegala, Monaragala, Hambanthota, Rathnapura and Badulla (Pushpakumari *et al*., 2006). This crop utilized as a vegetable is becoming an important ingredient in daily diet, but relativity little attention has been paid towards development of new varieties rich in carotenoids with high yielding capacities.

Morphologically, this crop species have prostrate spreading growth habit and can grow up to 25 feet long when the ideal field conditions are met. The leaves having three or five lobes are produced at the leaf axils. The root system is extensive and shallow (Kiramana and Isutsa, 2018). Pumpkins are monoecious crop having male and female flowers in separate structures on the same plant (Kiramana and Isutsa, 2018). Flowers consisted of

five petals that vary in size, shape and color with different shades of yellow (Aruah *et al*., 2010) and the ratio of male to female flowers ranges from 4: 1 to 17: 1 per plant (Agbagwa *et al*., 2007). The crop is considered as the largest fruit-bearing habit in the plant kingdom and the weight of the spherical fruits ranges between 0.5 kg to 50 kg (DOA, 2020), with moderately hard rind, thick, edible flesh and a central seed cavity with numerous tan or soft-white seeds, covered with a protective testa (Robinson and Decker-Walters, 1997). Distinction of pumpkin cultivars is easiest by observing the morphological characteristics *viz;* fruit shape, size, stalk, stems and leaves, flesh quality, color and thickness, seed number and size (Paris, 2000; Hernandez *et al*., 2005).

The major limitation in pumpkin cultivation is known to be the shortage of improved varieties. To date, there is only one recommended pumpkin variety has been released by the Department of Agriculture namely ANK Ruhunu (Pushpakumari *et al*., 2006). Most of the farmers who cultivate pumpkin in Sri Lanka prefer hybrid variety- 'Arjuna', owing to their superior agronomic and yield characteristics. This situation has been alleviated due to the lack of locally developed promising varieties. Hence, farmers have to recurrently purchase seeds for every season hence, leading to high cost of production, while on the other hand, some imported varieties show low adaptability to local conditions. (Pushpakumari *et al*., 2006). This situation implies the necessity of a successful local breeding program for developing pumpkin varieties.

Collection and characterization of germplasms are essential for any crop improvement program to develop varieties focusing on improved yield and quality (Upadhyaya, 2008). Morphological description using qualitative and quantitative traits can be used to provide information on genetic variability, identification and classification of crops (Bianchi *et al*., 2016). Even though a wider number of pumpkin germplasms are available in Sri Lanka, proper characterization and evaluation have not been performed until recently. Therefore, the objectives of the present study were to morphologically characterize pumpkin accessions obtained from Plant Genetic Resource Centre, Gannoruwa, to evaluate their yield characteristics and to identify the best germplasm for future crop improvement programs.

II. MATERIALS AND METHODOLOGY

A. Experimental site and treatments

The research study was carried out at Agriculture Research and Development Center, Girandurukotte which is situated in the intermediate low country dry zone (IL_2) during the *Maha* season of 2020. Land was ploughed to fine tilt for easy and uniform germination of pumpkin seeds. The topsoil was mixed with 5kg of compost and raised beds were prepared with designated planting holes. A total of seven pumpkin accessions (Table 2) were obtained from Plant Genetic Resource Centre, Gannoruwa. Fields experiment was arranged in a Randomized Complete Block Design (RCBD) having three replicates. The unit plot size was 7.5m x 7.5m and pumpkin seeds were sown with the spacing of 2.5 m x 2.5 m. Prior to this, basal dressings were applied five days before seeding with Urea, TSP, MOP at the rates of 75 (kg/ha), 195 (kg/ha) and 60 (kg/ha) respectively. Subsequently, first and second top dressings were done with Urea and MOP at the rates of 75 (kg/ha) and 60 (kg/ha) at 4 weeks and 8 weeks after planting. Manual irrigation was practiced in accordance with the prevailed weather conditions and crop growth and developmental stages. The remaining all agronomic practices were followed according to the recommendations of Department of Agriculture, Sri Lanka.

B. Data collection and statistical analysis

Data collection was initiated from the onset of flowering stage and recorded from each pumpkin accession from the field plots. The quantitative crop traits were recorded in the following manner. The vine length, leaf length and width were measured from the average of five leaves per plot. Subsequently, data on number of days taken to 50 % flowering (male and female flowers) were recorded. At physiological maturity stage, the fruits were harvested and data related to fruit characters and yield were recorded. Fruit circumference, flesh thickness at maximum fruit diameter, mature fruit weight and yield per plant from the average of five fruits were recorded as previously mentioned by Pushpakumari *et al*. (2006). The fruit sample weights were measured using an electronic weighing balance.

Moreover, the qualitative crop characteristics were also recorded (Table 1). Leaf shape and flower colour and fruit characteristics at physiologically matured stage were assessed.

Table 1: Descriptors of qualitative characteristics used to characterize pumpkin accessions, (IPGRI, 2007)

Characteristics	**Descriptors**
Fruit shape	1.Globular, 2.Flattened, 3.Disk, 4.Oblong blocky, 5.Elliptical, 6.Acron, 7.Pyriform, 8.Dumb- bell, 9.Elongation form, 10.Turbinate superior, 11.Crowned, 12.Turbinate inferior, 13.Curved, 14.Crooked neck
Fruit ribs	0.No ribs, 1.Rounded, 2.Intermediate, 3.Deep
Shape of fruit ribs	0.No ribs, 2. Rounded, 2. Intermediate, 3.V-shaped
Flower color	1.Orange, 2.yellow
Predominant fruit skin color	1.Green, 2.Blue, 3.Cream, 4.Yellow 5.Orange, 6.Red, 7.Pink, 8.Brown, 9.Grey, 10.Black, 11.Other
Secondary fruit skin color	0.No secondary skin color, 1.White, 2.Green, 3.blue, 4.Cream, 5.Yellow, 6.Orange, 7.Red, 8.Pink, 9.Other (specify)
Flesh color	1. White, 2.Green, 3.Yellow, 4.Orange, 5.Salmon.
Seed color	1.White, 2.Cream, 3.Yellow
Leaf shape	1.Reniform, 2.Ovate

The guide for the scoring of leaf shapes, fruit shape, fruit ribs characters, predominant and secondary skin color, flesh color, seed color were assessed based on the International Plant Genetic Resources Institute (IPGRI) descriptors for *cucurbitaceae* (IPGRI, 2007). Moreover, a reference color chart was used to determine the color of flower, fruit and seeds.

Finally, the data generated from the experiment were statically analysed using SPSS statistical software. The quantitative data of each parameter were tested using one-way ANOVA and treatment means were separated by Duncan's Multiple Range Test (DMRT) at a 5 % significant level. Then for qualitative data were analysed by employing two multivariate analysis methods *viz*; Principal Component Analysis (PCA) and hierarchical cluster analysis and based on the outcomes, the experimental results were interpreted.

III. RESULTS AND DISCUSSION

A. Quantitative characteristics related to vine and leaf

The quantitative characteristics of pumpkin accessions were responded to differently and are shown in Table 2 &3. The vine length varied from 2.5 m to 3.9 m and showed significant variations among genotypes (p<0.01, Table 2). Accessions ACC# 132 (T4) and Thirunaweli (T6) had the higher vine length (3.9 m) while accession SPK# 05 (T1) had produced the shortest (2.5 m). The leaf parameters were measured, according to the data, accessions ACC# 516 (T2) and Wellawaya (T7) recorded the highest leaf length (19.5 cm), while Thirunaweli (T6) recorded the lowest (14.3 cm, p<0.01). Similarly there were significant variations were displayed for leaf diameter (p<0.01) ranging from 12.0 – 21.5 cm (p<0.01) where the difference was seen around 9cm. The highest leaf diameter was observed in ACC# 135 (T5, 21.5 cm) while the lowest in ACC# 00088 (T3, 12.0 cm).

According to the analysis, the variations exists among the pumpkin accessions for vine length, leaf parameters which may result in diverse in leaf number, size and shape, as a result, this may lead to provide variations among green area obtained for a particular plant accession. This may have a direct impact on determining plant photosynthesis and carbohydrate metabolisms and eventually crop yield. Interestingly, accession Thirunaweli recorded the lowest leaf parameters though the vine length was higher, hence, it is presumed that more leaves can be produced along the vine compare to other accessions, thereby that may contribute to improved photosynthesis. The variation in vine length further exhibit the diversity among the accessions to plant breeders and farmers, elucidating that new pumpkin varieties can either be produced with longer or relatively shorter size canopies.

B. Days taken to 50 % flowering

Based on the results of the present study, there were significant variation observed for the days taken to 50% flowering of female flowers (pistilated flower) among the genotypes (p<0.01, Table 2). According to the analysis, the number of days taken ranged between 33 to 36 days. Accession ACC# 516 (T2) required the maximum

number of days (36 days) to flower whilst earliest (33d) was observed in accessions ACC# 132 (T4), ACC# 135 (T5) and Thirunaweli (T6). Though, no significant differences were observed in days taken to male flowering (staminated flower) among the genotypes (34d).

These observation contradicts to the existing knowledge, that most of the pumpkin requires 52 to 88 days to flower from the date of field planting (Pushpakumari *et al*., 2006; Mendligner *et al.*, 1992; Ahamed *et al*., 2012). According to these analyses, our tested accessions seems to flower much earlier (33 to 36 days) than the commercial varieties.

Table 2: Leaf, stem parameters and flowering dates of seven pumpkin accessions tested in the field.

Treatments	Pumpkin accessions	Vine length (m)	Leaf Length (cm)	Leaf Diameter (cm)	Days to Flowering (Male)	Days to Flowering (Female)
T1	SPK# 05	2.5±0.1^{a}	15.2±0.2^{ab}	12.4±0.2^{a}	34±0.0^{a}	35.3±0.3^{a}
T2	ACC# 516	3.1±0.1^{bc}	19.5±0.6^{d}	12.8±1.9^{a}	34.7±0.3^{a}	35.7±0.3^{a}
T3	ACC# 00088	2.7±0.1^{ab}	16.2±0.1^{bc}	12.0±0.2^{a}	34±1.0^{a}	34.7±0.3^{c}
T4	ACC# 132	3.9±0.0^{c}	17.4±0.3^{c}	13.9±0.2^{ab}	33.7±0.7^{a}	33±0.0^{b}
T5	ACC# 135	2.7±0.1^{ab}	15.5±0.3^{ab}	21.5±0.3^{c}	34.3±0.7^{a}	33±0.0^{b}
T6	Thirunaweli	3.9±0.0^{d}	14.3±1.1^{a}	12.5±0.0^{a}	34.7±0.3^{a}	33±0.0^{b}
T7	Wellawaya	3.2±0.3^{c}	19.5±0.7^{bc}	15.3±0.2^{b}	34.7±0.3^{a}	34±0.0^{d}
Mean		3.1	16.4	14.4	34.3	34.1
F-value (df)		11. 003 (20)	11.324 (20)	19.051 (20)	0.517 (20)	27.778 (20)
P-value		<0.001	<0.001	<0.001	0.786	<0.001
C.V		15.9	10.8	23.4	2.6	3.3

The values are means of each quantitative parameter ± standard error mean (SEM). The superscript with different letters indicates significant differences exists between pumpkin accession (p-value < 0.05), means followed by the same letter in each column are not significantly different by Duncan's multiple range test at p=0.05.

Table 3: Fruit characteristics of seven pumpkin accessions tested in the field.

Treatments	Treatments	Fruit circumference (cm)	Flesh thickness (mm)	Yield (kg/plot)	Yield per plant (kg)
T1	SPK# 05	54.7±0.9^{a}	1.9±0.2^{ac}	23.7±5.9^{ab}	4.7±1.1^{ab}
T2	ACC# 516	65.3±0.9^{a}	2.0±0.0^{abc}	27.8±2.3^{b}	5.6±0.5^{b}
T3	ACC# 00088	60.0±2.3^{a}	2.4±0.1^{c}	15.0±2.8^{a}	3.0±0.6^{a}
T4	ACC# 132	62.0±1.5^{a}	2.3±0.1^{bc}	20.3±2.3^{ab}	4.1±0.5^{ab}
T5	ACC# 135	63.0±2.3^{a}	2.0±0.2^{ab}	21.1±4.8^{ab}	4.2±0.1^{ab}
T6	Thirunaweli	64.7±4.8^{a}	2.3±0.0^{bc}	47.9±2.7^{c}	9.6±0.5^{c}
T7	Wellawaya	61.7±0.9^{a}	2.3±0.1^{bc}	28.2±2.9^{b}	5.6±0.6^{b}
Mean		61.6	2.2	26.3	5.3
F-value (df)		2.289 (20)	2.990 (20)	8.444 (20)	8.440 (20)
P-value		0.095	0.043	0.001	0.001
C.V		7.8	12.6	43.1	43.2

The values are means of each quantitative parameter ± standard error mean (SEM). The superscript with different letters indicates significant differences exists between pumpkin accession (p-value < 0.05), means followed by the same letter in each column are not significantly different by the Duncan's multiple range test at p=0.05.

C. Quantitative characteristics related to yield

Pumpkin accessions were significantly differed in yield ranging from 9.6 to 3.0 kg. Based on the experiment, Thirunaweli (T6) gave the highest yield (9.6 kg/plant) followed by Wellawaya (T7) (5.6 kg/plant) and ACC# 516 (T2) (5.6 kg/plant), while the least yield was obtained in ACC# 00088 (T3) (3.0 kg/plant), hence it was found that Thirunaweli had produced the double the yield than the other tested counterparts (Table 3). According to the analysis, there were no significant variations were observed in fruit circumference (p=0.09), though, flesh thickness were significantly varied (p<0.05), ranged between 1.9 – 2.4 mm where, the lowest thickness was seen in SPK# 05 (T1) (1.9 mm) and the highest thickness was seen in ACC# 00088 (T3) (2.4 mm) followed by ACC# 132 (T4), Thirunaweli (T6) and Wellawaya (T7).

Overall, the exploration of local accessions was vital as it identifies the latent potentials of pumpkin accession, Here it was evident that germplasm Thirunaweli has the similar yielding capacity same as the elite commercial hybrid 'Arjuna' (9.83 kg/plant) in the local climatic conditions. According to Grubben and Ngwerume, (2004), pumpkin varieties yield range from 1 – 10 kg per plant. The observations can be explained in the basis of plant physiology, crop yield can have a direct correlation between the canopy size and the amount of photosynthates produced within the plant. The larger the green canopies are preferred, in Thirunaweli germplasm possessed with long vines with numerous smaller leaves may have led to increased leaf area. So as a consequence produced a remarkably increase in fruit yield compared to the other pumpkin accessions.

D. Qualitative characteristics of pumpkin accessions

The qualitative traits expressed by the pumpkin accessions were differed from each other and some of them showed interesting features. The reniform leaf shape was prominent among six accessions, while for accession Wellawaya had produced leaves with unique ovate shape. Hence, this germplasm can be easily distinguished at the early stages of crop development based on the unique leaf morphology. According to the recorded data, all accessions had produced yellow flowers and no variations were seen (Table 4). Then the fruit morphological characteristics were analyzed. The predominant shape of the fruit was flattened and observed in five accessions (Table 4). However, a unique fruit shape was observed in ACC# 516 (globular) and Thirunaweli (cylindrical). Hence, accessions ACC# 516 and Thirunaweli can be easily identified based on the fruit shape. According to Xolisa (2002), reports that fruit shape ranged from cylindrical, oblate, flattened and globular to elliptic. In addition, Labrada *et al*. (1997), reported pyriform and crookneck types are some of the main fruit shapes in pumpkins.

Table 4: Qualitative characteristics of seven pumpkin accessions tested in the field

Accession	Leaf shape	Flower color	Fruit characteristics			Fruit skin color			Seed color
			Shape	No. of Ribs	Ribs shape in cross Section	Predominant	Secondary	Flesh color	
Spk#05	Reniform	Yellow	Flatten	Intermediate	Rounded	Green	Cream	Yellow	White
ACC# 516	Reniform	Yellow	Globular	Intermediate	Rounded	Cream	Cream	Yellow	Cream
ACC# 00088	Reniform	Yellow	Flatten	Intermediate	Rounded	Green	Orange	Yellow	Yellow
ACC# 132	Reniform	Yellow	Flatten	Intermediate	Rounded	Green	Orange	Yellow	Yellow
ACC# 135	Reniform	Yellow	Flatten	Intermediate	Rounded	Green	Cream	Orange	Yellow
Thirunaweli	Reniform	Yellow	Cylindrical	Intermediate	Rounded	Green	Cream	Orange	Yellow
Wellawaya	Ovate	Yellow	Flatten	Intermediate	Rounded	Cream	Cream	Orange	Cream

Qualitative traits were assessed based on the International Plant Genetic Resources Institute (IPGRI) descriptors for *cucurbitaceae* (IPGRI, 2007). A reference color chart was used to determine the color of fruit, flower and seeds.

Moreover, based on the present investigations, the predominant fruit skin color was ranged from green to cream color and the secondary fruit skin color ranged from orange to cream. In accession ACC# 516 and Wellawaya, the prominent and secondary skin were same and expressed a unique crème colour than the other tested germplasms. Mladenovic *et al*. (2014) reported that predominant fruit skin color ranges from green to orange, and secondary pattern from speckled to stripe. Ahamed *et al*. (2012) reported that the fruit color range from green yellow to brown. Furthermore, Paris and Brown (2005) reported that the color of fruit skin is controlled by 3 loci (*Gr, Mldg* and *B*). Dominant *Gr* results in green fruits, *Mldg* mottled immature fruit color and *mldg* non-mottled rind, while B (*Bicolor)* gene confers a precocious yellow color. Hence the interaction of the above three genes might have produced the unique crème colour in accession ACC# 516 and Wellawaya.

The color of internal flesh varied from yellow to orange. Accession ACC# 135, Thirunaweli and Wellawaya had produced orange colored internal flesh while the remainder accessions had yellow. Though, Ahamed *et al*. (2012) reports and the flesh color may range from whitish to greenish in pumpkin accessions. Moreover, based on the results, all tested pumpkin accessions had produced intermediate and rounded type of fruit ribs and there were no differences were seen for this morphological trait. Hence, fruit characteristics such as flesh thickness, color, and fruit rib morphologies cannot be used to identify the pumpkin accessions used in this study.

The seed morphology were assessed. The predominant seed coat color ranged from white and cream to yellow. A unique white-seed coat was produced by accession SPK# 05, though ACC# 516 and Wellawaya had expressed cream color (Table 4). According to Kiramana and Isutsa (2018), cream-yellow colored seed coats in most promising among the pumpkin accessions while Aruah *et al*. (2010) reported obtaining brown and light-brown seeds are also possible.

E. Hierarchical cluster analysis of qualitative traits

According to cluster analysis, the pumpkin genotypes were grouped into two major clusters and 3 sub-clusters based on qualitative traits. Cluster one contained 2 sub-clusters and one of them had 3 accessions (ACC# 00088, ACC # 132 and ACC# 135). The other one had displayed with accessions ACC# 516, Wellawaya and SPK# 05. Interestingly, Cluster 2 had only one unique accession, Thirunaweli (Figure 1).

F. Hierarchical cluster analysis of quantitative traits

Based on the Cluster analysis of quantitative traits, pumpkin genotypes were classified into two major clusters and they were further divided into 4 sub-clusters. Cluster one contained 3 sub-clusters, each having 2 accessions ACC# 516 and Wellawaya), 3 accessions (ACC# 00088, ACC # 132 and SPK# 05) and 1 accession (ACC# 135) respectively. Importantly, Cluster 2 consisted only one accession Thirunaweli (Figure 2). Based on these findings, it clearly shows that accession Thirunaweli has unique qualitative and quantitative characteristics than that of other germplasms, hence the morphological characteristics can be used to distinguish from each other.

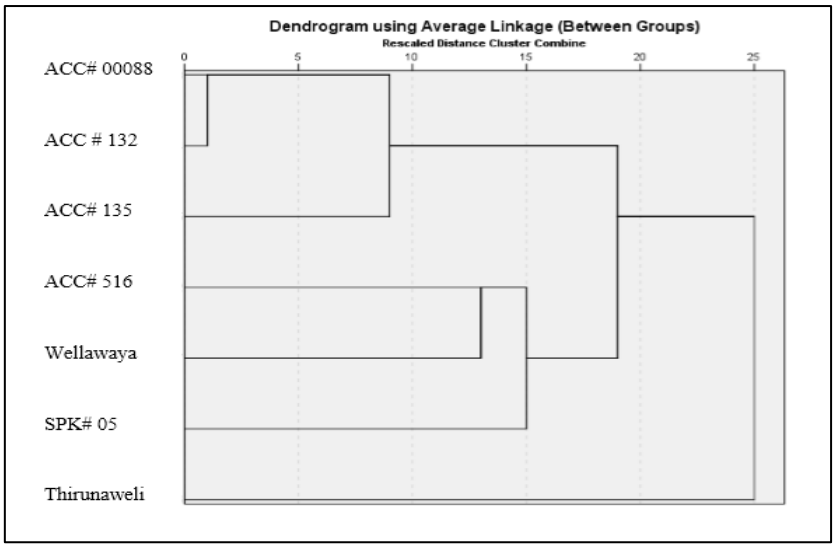

Figure 1: Dendrogram generated based on qualitative characteristics in 7 pumpkin accessions

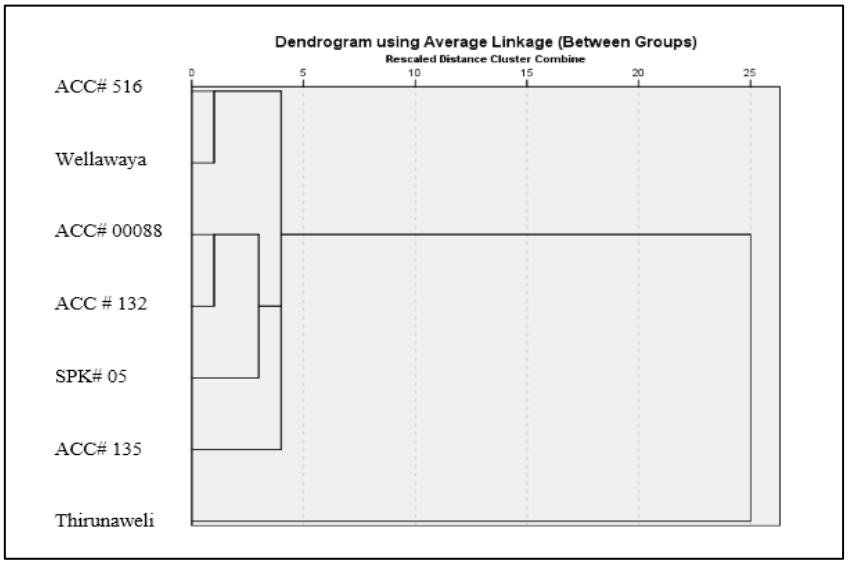

Figure 2: Dendrogram generated based on quantitative characteristics in 7 pumpkin accessions

IV. CONCLUSION

Seven pumpkin accessions from Plant Genetic Resource Center, Gannoruwa were characterized for morphological and yield traits. It was found that significant variations were seen among tested germplasms for their morphological and yield traits. Therefore, it can be concluded that pumpkin accession can be characterized according to morphological traits such as leaf traits, fruit skin colour, and the nature of seed coat. Based on the overall performance, accessions Thirunaweli and Wellawaya produced improved crop yield and can be suggested for crop improvement programs. Moreover, this study did not focus on measuring the crop resource uses efficiency to water, fertilizer and sunlight, or tolerance to biotic and abiotic stress, Hence, future efforts addressing such avenues combined with DNA profiling techniques is vital.

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