Morphological and Yield Performance of Chinese and Rangoon Ginger (*Zingiber officinale* Roscoe) Accessions Cultivated as Intercrops under Coconut Cultivation in the Low Country Intermediate Zone of Sri Lanka

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Abstract

Ginger (Zingiber officinale) belongs to the family Zingiberaceae. Chinese, Rangoon and Local are the commonly cultivated ginger types in Sri Lanka. Local ginger is rich in fiber, uses in Indigenous and Ayurveda medicinal purposes, and amount of yield is comparatively low. Chinese and Rangoon are moderately in pungency, amount of yield is comparatively high and use in beverage industry likes for production of ginger beer and for culinary purposes also. Ginger can be grown either as a mono-crop or inter-crop under coconut plantation. This research was carried out at Inter-cropping and Betel Research Station, Narammala where the area belongs to Kurunegala district is under the coconut triangle. Coconut plants are generally spaced in 26 ft x 26 ft, hence 75% of area under the coconut plants are remaining unproductively. Underutilized area is high when the age of the coconut plants is below 5 years and over 20 years. Climatic conditions in Kurunegala district is more favourable for ginger cultivation. After the three years field experiment, the highest fresh yield of rhizome per clump for Chinese ginger accessions was given by the accession of G33 (949.2 g/clump) in Low Country Intermediate Zone under coconut cultivation. The highest fresh yield of rhizome per clump for Rangoon ginger accessions was given by the accession of G28 (754.2 g/clump) in low country Intermediate zone under coconut cultivation. The G28 and G33 accessions can be used to cultivate under coconut plantation as an intercrop to increase the productivity of coconut lands.

Keywords: Chinese ginger accessions, Rangoon ginger accessions, Evaluation

I .INTRODUCTION

Ginger is scientifically known as *Zingiber officinale* Roscoe and belongs to the order *Zingiberales* and the family *Zingiberaceae*. It is common in Southeast Asian countries and primarily cultivated in India. Ginger is a perennial herbaceous plant. The true stem of the plant lies underground and the above ground part is called the pseudo stem.

There are three main types of ginger grown in Sri Lanka: Chinese ginger, Rangoon ginger and native ginger. In addition, different types of ginger are cultivated around the world. Local ginger is high in pungency, rhizome is rich in fiber, uses in Indigenous and Ayurvedic medicinal purposes, and yield is comparatively low. Chinese and Rangoon are moderately in pungency, amount of yield is comparatively high and are often used in beverage industry likes for production of ginger beer and for culinary purposes.

Total cultivated extent of ginger in year 2022/2023 was 2,383 ha and the total production was 19,375 mt. Kurunegala, Gampaha, Kandy, Badulla and Rathnapura were the major growing districts of ginger in year 2022 / 2023 cultivated extent of these districts were 774, 280, 188, 142 and 129 ha respectively .Ginger production in the districts of Kurunegala, Gampaha and Kandy were 7,352, 2,662 and 1,692 ha respectively (Anonymous, 2023). Ginger can be grown either as a mono-crop or inter-crop under coconut plants. Coconut plants use a large volumes of air space and it limits to increase the crop density. Efficient utilization of air space is important. Coconut palms are generally spaced 8 m x 8 m resulting in 75% of area remaining unproductive. Underutilized area is high when the age of the coconut palm is below 5 years and over 20 years. Therefore, coconut based intercrops farming systems is important to increase the productivity of the land (Liyanege *et al.*, 1986).

There were no identified high yielding ginger accessions. For that cultivation of Chinese and Rangoon ginger is more profitable due to high yield rather than that of Local ginger.

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The objectives of the study were to evaluate the morphological characteristics and identify high-yielding accessions of Chinese and Rangoon ginger (*Zingiber officinale* Roscoe) for cultivation as intercrops under coconut cultivation in the Low Country Intermediate Zone of Sri Lanka.

II. MATERIAL AND METHOD

A. Collection of ginger accessions-

Field surveys were done to collect ginger accessions and survey information like farmers' details, information on crop management practices were recorded on questionnaires. Different accessions of ginger were collected from the districts of Kurunegala, Gampaha, Kalutara, Galle, Matara, Hambantota, Monaragala, NuwaraEliya, Matale, Kegalle, Jaffna, Ampara, Kandy, Badulla, Rathnapura, Anuradhapura, Polonnaruwa, Puttalam and Colombo. Germplasm were collected from the different Extension Officers' rangers level within the district.

B. Multiplication of ginger accessions-

Collected ginger accessions were established in the research field, at Intercropping and Betel Research Station (IBRS), Department of Export Agriculture, Dampelessa, Narammala, Sri Lanka for further growth of ginger rhizomes. It is situated in Low country Intermediate zone, agro-ecological region IL1a Longitude is 80.22^0E and Latitude is 7.43^0N. Elevation is 63m from mean sea level. Average day time temperature is 28-30^0C. Narammala typically receives about 1900 mm of precipitation and has around 192 rainy days annually. Mean humidity is 76.8% (Weather and Climate, 2020).

C. Evaluated ginger accessions-

1) Evaluated Chinese type ginger accessions-

Altogether there were 14 Chinese type ginger accessions were collected by field surveying. One wild type ginger accession was also found. That was more or less similar to Chinese type ginger. Out of the collected all Chinese ginger accessions, 5 accessions were considered for the evaluation. Because of the amount of the rhizomes of the rest of the Chinese type ginger accessions, were not sufficient for establishment of a 3 replicates of field experiment. These Chinese type ginger accessions were numbered as G1, G2, G3, G17 and G33.

2) Evaluated Rangoon type ginger accessions-

Altogether there were 18 Rangoon type ginger accessions were collected by field surveying. Out of the collected all Rangoon ginger accessions, 7 accessions were considered for the evaluation, because the amount of the rhizomes of the rest of the Rangoon type ginger accessions were not sufficient for establishment of a 3 replicates of field experiment. These Rangoon type ginger accessions were numbered as G6, G9, G27, G28, G29, G30 and G34.

D.Establishment of ginger accessions evaluation fields and management practices- .

This research was carried out during the period of 2015-2023, at Intercropping and Betel Research Station (IBRS), Department of Export Agriculture, Dampelessa, Narammala, Sri Lanka. Evaluation for ginger was done as an intercrop under the coconut cultivation. Experimental design for evaluation field was Randomized Complete Block Design (RCBD) with 3replicates. The field was ploughed up to 35 cm-40 cm in depth and tilling of soil was done. Raised beds of 3.05 m x 1.22 m (10 ft x 4 ft) were prepared. Field establishment was done in *Yala* season in month of April. Five Chinese type ginger accessions, and seven Rangoon type ginger accessions were taken for the evaluation. These considered accessions had sufficient amount of rhizomes for 3 blocks. There is no any recommended ginger accessions given by the Department Export Agriculture for cultivation. Thirty grams of rhizomes weight for each accession was used for planting of Rangoon ginger and 40g of rhizomes weight from each accession was used for planting of Chinese ginger . Spacing between rows and between plants were 25 cm x 25 cm. Sprinkler irrigation was practiced for ginger cultivation. Department recommended management practices were followed for evaluation. One hundred kilograms of Triple Super Phosphate was applied as basal dressing per hectare. Eighty two kilograms of Urea and 42 kg of Muriate of Potash were applied for a hectare, at 45 days after establishment of ginger rhizomes. Eighty two kilograms of Urea and 42 kg of Muriate of Potash were applied for a hectare, at 90 days after establishment of ginger rhizomes. Always ginger beds were covered by using a mulch. Harvesting was done at nine months after the planting when the leaves become like straw.

E. Collection of ginger data-

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Both morphological and yield data were collected. Height of the pseudo-stems, number of pseudo-stems per clump, number of leaves per pseudo-stem, leaf length and leaf width were measured at the 8 month after the planting. Nine month old matured fresh ginger rhizomes of each accessions were used for the weight evaluation. Cross sections of rhizomes were compared for colour using a Munsell Colour Chart (Plant). Fresh yield for each accessions was taken by randomly selecting 10 clumps per each replicates.

F. Analyzing of data-

Three consequent years, yield and morphological data were countered. Three year mean values were taken for the analysis. Mean separations were practiced using Statistical Analyzing Software (SAS) package. Leased Significant Difference (LSD) technique was used for the mean separation of the treatments.

III. RESULTS AND DISCUSSION

A. Evaluation of morphological characters-

Morphological characters of height of the pseudostem, no. of pseudostem per clump, no. of leaves per pseudostem, leaf length and leaf width were measured at the 8 month after the planting. Height of the pseudostem was measured from bottom of the plant to the top of the plant. Number of pseudostems per clump was taken by the counting. Number of leaves per pseudostem was also taken by the counting. Leaf length was measured from base to tip of the leaf. Maximum width of the leaf was taken as the leaf width.

1) Morphological characters of Chinese ginger

Mean values of morphological characters of Chinese ginger are shown in Table 01.

If the height of the pseudo-stem is higher it has more advantage, to capture penetrated sunlight through the coconut plants. The highest significant mean value for height of the pseudo-stem was recorded by the Chinese type ginger accession of G3 (59 cm) and the lowest value recorded by the accession of G17 (32.7 cm). There were no significant differences among the ginger accessions of G1 (33.8cm), G2 (32.8cm), G17 (32.7cm) and G33 (33.7cm) for height of the pseudo-stem.

Normally if a clump has higher number of pseudo-stems it will enhances the level of photosynthesis. There were no any significant differences among the accessions for number of pseudo-stems per clump. Number of pseudo-stems per clump varied from 7 to 5. Although they were not significant the highest value for number of pseudo-stems per clump was recorded by the Chinese ginger accession of G3 (7) and the lowest value recorded by the Chinese ginger accessions of G2 and G17 (5). According to a study done by Hossain *et al* (2019) higher number of pseudo-stems per clump during harvesting was observed in "deshi" variety (V1) (4.19) and lower number of tiller per plant was observed in china variety (V2) (3.70).

Number of leaves per pseudo-stem varied from 18 (G3) to 8 (G2). The highest significant number of leaves per pseudo-stem was given by G3 (18). There were no significant differences among the other accessions of G1, G2, G17 and G33.

Leaf lengths of Chinese ginger accessions varied from 21cm (G3) to 12cm (G1 and G33). There are no any significant differences of leaf length among the accessions of G1, G2, G17 and G33. The reason may be the these accessions are genetically somewhat similar.

Table 01: Mean values of morphological characters of Chinese ginger (At 8 months after the planting)- Means within a column with the same letter are not significantly different at P<0.05

Accession No.	Pseudostem height (cm)	No. of Pseudostems/ clump	No. of Leaves / Pseudostem	Leaf length (cm)	Leaf width (cm)
G6	35.2 bc	**10 ab**	9 b	14b c	1.9 cd
G9	38 b	5 b	**16 a**	12 c	1.8 d
G27	32 bc	2 b	9 b	13.3 bc	**2.2 ab**
G28	28 c	3 b	10 b	14 bc	2 bcd
G29	36.2 b	**11 ab**	**15 a**	16.5 b	2.1 bc

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G30	32.7 bc	**15 a**	10 b	13.2 c	2 bcd
G34	**55.2 a**	**15 a**	**15 a**	**21.2 a**	**2.4 a**
CV%	17	44	26	19	10

Leaf width varied from 2.5cm to 1.9cm . The highest significant different value for leaf width was indicated by the accession of G3(2.5 cm) and the lowest leaf width was indicated by the accession of G2 (1.9 cm).

If the leaf length and leaf width are higher values, leaf area of the accession is also high. Among the considered Chinese accessions, G3 was the most predominant accession for the morphological characters.

2) Morphological characters of Rangoon ginger- Mean values of morphological characters of Rangoon ginger are shown in Table 02.

Table 02: Mean values of morphological characters of Rangoon ginger (At 8 months after the planting)- Means within a column with the same letter are not significantly different at P<0.05

Accession No.	**Pseudostem height (cm)**	**No. of pseudostems per clump**	**No. of leaves / pseudostem**	**Leaf length (cm)**	**Leaf width (cm)**
G1	33.8^{b}	**6^{a}**	10^{b}	12^{b}	2^{b}
G2	32.8^{b}	**5^{a}**	8^{b}	14^{b}	1.9^{b}
G3	**59^{a}**	**7^{a}**	18^{a}	**21^{a}**	**2.5^{a}**
G17	32.7^{b}	**5^{a}**	9^{b}	14^{b}	2^{b}
G33	33.7^{b}	**6^{a}**	9^{b}	12^{b}	2^{b}
CV%	21	43	22	16	11

The height of the pseudo-stem was varied from 55.2cm to 28cm. The highest significant different value for height of the pseudo-stem was recorded by the Rangoon type ginger accession of G34 (55.2 cm) and the lowest value recorded by the accession of G28 (28 cm).

Number of pseudo-stems per clump varied from 15 to 2. The highest value for number of pseudo-stems per clump was recorded by the Rangoon ginger accession of G30 and G34 (15). But there were no any significant differences among the accessions of G6, G29, G30 and G34.The lowest value recorded by the Rangoon ginger accessions of G27 (2). Number of leaves per pseudo-stem varied from 16(G9) to 9 (G6 and G27). Leaf lengths of Rangoon ginger accessions varied from 21.2cm (G34) to 12cm (G9). Leaf width varied from 2.4cm (G34) to 1.8cm (G9). Among the considered Rangoon accessions, G34 was the most predominant accession for the morphological characters. Normally Chinese ginger has, higher pseudostem height and less number of pseudostems per clump than that of Rangoon ginger.

B. Evaluation of the colour of the rhizomes of ginger accessions -

Nine month matured fresh ginger rhizomes were used for the evaluation. Cross sections of rhizomes were compared with a Munsell Colour Chart (Plant) (Figure 01).

Figure 01: Cross Sections of Rhizomes of Ginger Accessions

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Table 03 shows the Munsell colour notations for rhizome of Chinese ginger accessions and Table 04 shows the Munsell colour notations for rhizome of Rangoon ginger accessions.

Table 03 : Munsell colour notations for rhizome of Chinese ginger accessions

Accession No.	Colour notation of the rhizome [according to Munsell Colour Chart (Plant)]
G6	5Y 8/6 to 8/8
G9	5Y 8/4
G27	5Y 8/4 to 8/6
G28	5Y 8/6 to 8/8
G29	5Y 8/8
G30	5Y 8/6 to 8/8
G34	5Y 8/6 to 8/8

Water, protein, lipids, fibres, starch, minerals and vitamins are the components of ginger rhizomes (Ginger, 2015).

Normally, the ginger rhizome is pale yellow in colour. A study was done for identify, what are the compounds that responsible for the yellow colour. In this study, 62 kinds of ginger rhizomes originating from different cultivars or different cultivation locations were collected for analysis of yellow pigment compounds. Ultra-performance liquid chromatography profiles at 420 nm for each sample were used for principal component analysis. Curcumin, demethoxy curcumin, and 6- dehydrogingerdione were identified as the main common compounds contributing to the yellow colour (Yoko I. *et al, 2014*).

Commonly cross sectional colour of core area of rhizome of Chinese ginger is bright yellow. All the colour notations of Chinese ginger accessions were differ from each other. That means their pigment compositions were differing from each other.

Commonly cross sectional colour of core area of rhizome for Rangoon ginger is light yellow. Most of the Rangoon ginger accessions (G6, G28, G30, G34) show 5Y 8/6 to 8/8 colour notation for cross section colour of rhizome.

Table 04 : Munsell colour notations for rhizome of Rangoon ginger accessions

Accession No.	Colour notation of the rhizome [according to Munsell Colour Chart (plant)]
G1	5Y 8/8
G2	5Y 8/6
G3	5Y 8/4 to 8/6
G17	5Y 8/8 to 8/10
G33	5Y 8/6 to 8/8

C. Evaluation yield of ginger accessions-

1) Fresh yield of the Chinese ginger-

Mean values of fresh yield of Chinese ginger is shown in Table 05.

Table 05: Mean values of fresh yield of the Chinese ginger

Accession no.	Fresh weight of the rhizome /clump (g)			
	1st year cultivated ginger	2nd year cultivated ginger	3rdyear cultivated ginger	Mean values of 3 years
G1	**1265.5^{a}**	**877.2^{a}**	546.1^{d}	896.3^{b}
G2	1219.8^{abc}	723.8^{ab}	596.5^{c}	846.7^{c}
G3	1245.5^{ab}	697^{ab}	557.2^{d}	833.2^{c}
G17	1113.6^{c}	565.3^{b}	648.5^{b}	775.8^{d}
G33	1113.5^{c}	627.7^{b}	**1106.4^{a}**	**949.2^{a}**
CV%	30.4	13.9	20.3	13.5

Means within a column with the same letter are not significantly different at P<0.05

In first year, the highest fresh yield was given by the accession of G1 (1265.5 g/clump). But it was not significant different with the accessions of G3 (1245.5 g/clump) and G2 (1219.8 g/clump). The lowest fresh yield was given by the accession of G33 (1113.5 g/ clump).

In second year, fresh yield for all the accessions were lower than the yield of first year. It is may be

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the unfavourable weather condition of the second year. The highest fresh yield was given by the accession of G1 (877.2 g/clump). But it was not significant different with the accessions of G2 (723.8 g/clump) and G3 (697.0 g/clump). This is more or less similar to first year yield. The lowest fresh yield was given by the accession of G17 (565.3 g/ clump).

In third year, the significant highest yield was given by the accession of G33 (1106.4 g/clump). The lowest yield was given by the accession of G1 (546.1 g/clump). Besides the yield of G33, yields of the rest of the accessions in the third year, were lower than that of first year. The reason may be the weather conditions gave a negative impact on the yield of the accessions of G1, G2, G3 and G17 but not an adverse effect on the yield of G33, in third year due to some genetical reason.

Three year mean values for fresh yield of rhizome varied from 949.2 to 833.2 g per clump. When considered three years average yield of Chinese ginger, G33 accession gave the highest yield of 949.2 g/clump (10,441 kg/Ac). Therefore G33 accession is more suitable for cultivate under coconut plants as an intercrop.

The vegetative growth and development of ginger are divided into two phases. First phase is the rapid growth phase, that is increased growth rate of plant height followed by rhizome development phase. Throughout the second phase, enlargement and expansion of ginger rhizome is happened (Soni J. K., *et. al*.,2022).

Although the predominant vegetative growth was indicated by the Chinese accession of G33, the highest fresh yield was given by G33 accession. The reason for this type of situation may be the large amount of synthesized food was utilized for vegetative growth, and remaining only a small amount of synthesized food for the storage in rhizome.

Table 06: Mean values of fresh yield of the Rangoon ginger

Accession no.	Fresh weight of the rhizome /clump (g)			
	1st year cultivated ginger	**2nd year cultivated ginger**	**3rdyear cultivated ginger**	**Mean values of 3 years cultivated ginger**
G6	**749.4^{a}**	538.5^{d}	538.8^{d}	608.9^{d}
G9	671.8^{b}	543.3^{d}	552.8^{d}	589.3^{d}
G27	681.4^{ab}	703.3^{abc}	720.2^{b}	701.6^{b}
G28	**729.5^{ab}**	**801.3^{a}**	731.8^{b}	**754.2^{a}**
G29	696^{ab}	**764.3^{ab}**	**749.8^{a}**	**736.7^{ab}**
G30	**690^{ab}**	644.3^{bcd}	589.1^{d}	641.1^{c}
G34	**684^{ab}**	590.3^{cd}	658.6^{c}	644.3^{c}
CV%	35.4	11.7	20.6	11.7

Means within a column with the same letter are not significantly different at P<0.05

2) Fresh yield of the Rangoon ginger

Mean values of fresh yield of Rangoon ginger is shown in Table 06

In first year, the highest fresh yield was given by the accession of G6 (749.4g/clump). But it was not significant different with the accessions of G27, G28, G29, G30 and G34. The lowest fresh yield was given by the accession of G9 (671.8 g/ clump).

In second year, the highest fresh yield was given by the accession of G28 (801.3 g/clump). But it was not significant different with the accessions

of G29 (764.3 g/clump) and G27 (703.3g/clump). The lowest fresh yield was given by the accession of G6 (538.5 g/ clump).

In third year, the significant highest yield was given by the accession of G29 (749.8 g/clump). The lowest yield was given by the accession of G6 (538.8 g/clump).

Mean fresh yield of rhizome varied from 754.2 to 589.3g per clump. When considered three years average yield of Rangoon ginger, G28 accession gave the highest yield of 754.2 g/clump (4,977.7kg/ ac).

Commonly Chinese ginger yield is higher than Rangoon ginger yield. Although the predominant vegetative growth was indicated by the Rangoon accession of G34, the highest fresh yield was given by G28 accession. The reason for this type of situation may be the large amount of synthesized food was utilized for vegetative growth, and remaining only a small amount of synthesized food for the storage in rhizome.

IV. CONCLUSIONS

This research was carried out at Inter-cropping and Betel Research Station, Narammala. This area belongs to Kurunegala district. Kurunegala district is under the coconut triangle. Coconut plants are generally spaced in 26 ft x 26 ft. Due to this reason in 75% of area under the coconut plants are remaining unproductively. Underutilized area is high when the age of the coconut plants is below 5 years and over 20 years. Climatic conditions in Kurunegala district is more favourable for ginger cultivation. After the three years field experiment, the highest fresh yield of rhizome per clump for Chinese ginger accessions was given by the accession of G33 (949.2 g/clump) in Low Country Intermediate Zone under coconut cultivation. The highest fresh yield of rhizome per clump for Rangoon ginger accessions was given by the accession of G28 (754.2 g/clump) in low country Intermediate zone under coconut cultivation. The G28 and G33 accessions can be used to cultivate under coconut plantation as an intercrop to increase the productivity of coconut lands. Further research is required to identify the performances of this accession in other agro-ecological regions besides low country intermediate zone.

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