A NUMERICAL ANALYSIS OF MORPHOLOGICAL AND ANATOMICAL CHARACTERISTICS IN MALAYSIAN SPECIES OF THE AROIDS GENUS *Scindapsus* Schott

Kartini Saibeh

Institute for Tropical Biology and Conservation
Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia.

ABSTRACT. *The 17 Malaysian Scindapsus species were investigated numerically using morphological and anatomical characters. These data were used to establish interspecies relationships. Numerical analyses, using MVSP Plus Version 2.2 on the data matrix containing 37 characters, were employed concentrating on nearest neighbour cluster analysis and furthest neighbour cluster analysis. The analyses show three constant clustered groups: (1) Scindapsus beccarii and S. crassipes, (2) S.hederaceus, S. pictus, S. perakensis and S. longistipitatus and, (3) S. coriaceus, S. rupestris and S. borneensis. This study proposed S. havilandii be excluded from the genus Scindapsus*.

INTRODUCTION

The genus *Scindapsus* is a climbing aroid with a woody vein. The natural range of *Scindapsus* species is from northeastern India to western Polynesia (Bogner and Boyce, 1994). The potential economic importance of *Scindapsus* lies in its medicinal and ornamental uses. This genus was first published by H. W. Schott (Schott and Endlicher, 1832) in "Meletemata Botanica" and was characterized by a deciduous spathe and unilocular ovary. The last treatment by Engler and Krause (1908) had separated the genus into two main groups based on stigma shape: round or elliptic. The species were delimited by inflorescence and leaf morphology. Saibeh (2001) recognized 16 *Scindapsus* species recorded in Malaysia. Though common and abundant in the wild, Malaysian *Scindapsus* species are poorly-named, especially herbarium specimens, principally because the classification and identification of this genus is not yet properly established.

Scindapsus crassipes was described by Engler in 1881 (Engler and Krause, 1908). Then in 1908, he treated *S. crassipes* as a synonym to *S. beccarii* Engl.. Ridley (1925) also treated *S. crassipes* as the same species as *S. beccarii*. *Scindapsus borneensis* Engl. & K. Krause and *S. rupestris* Ridl. are always confusedly named, especially in dried sterile herbaria as they have a remarkably similar vegetative morphology. *Scindapsus hederaceus*, *S. perakensis* Hook. f. and *S. longistipitatus* Merr. are very similar in appearance especially in the juvenile form. The herbarium specimen of *S. lucens* Bogner & P.C. Boyce described by Bogner and Boyce in 1994 was collected by Dr. King's collector, No. 11125, dated April 1883 at Larut, Perak. Bogner and Boyce (1994) described *S. lucens* as closely related to *S. pictus* Hassk. especially based on leaf characters. *Scindapsus coriaceus* Engl. distinguished by having two ovules and *S. havilandii* Ridl. is a distinct species by having multiple inflorescences and ovules. *Scindapsus curranii* Engl. & K. Krause, *S. scortechinii* Hook.f. and *S. borneensis* are cool climate plants. *Scindapsus geniculatus* Engl. and *S. glaucescens* (Engl. & K. Krause) Alderw. are both recorded from Borneo. *Scindapsus latifolius* M. Hotta and *S. longipes* Engl. are recorded from Sarawak and Brunei. *Scindapsus latifolius* differs from the later by having a superficial exposure of trichosclereids.

An analysis was needed to clarify and illustrate the degree of relationship or similarity within the species. In this study, Similarity Estimation in the numerical analyses was used to summarise the overall similarity relationships among the species. The characters used in the analyses were based on morphology and anatomy studies. In the numerical analysis, it is advantageous to have as much data as possible from as many sources as possible. The characters chosen will provide a different type of relationship depending from where the data were obtained (Stace, 1966).

MATERIALS AND METHODS

Seventeen herbarium specimens of Malaysian *Scindapsus* species at the Royal Botanic Gardens, Kew, were studied. Type specimens at the Herbarium Universitatis Florentinae, Florence, were also studied. Data were accumulated from selected collections (Table 1) based on good specimens of adult plants, complete with leaf, stem, root and inflorescences.

Table 1: List of studied voucher specimens

Species	Vouchers
1. *Scindapsus beccarii* Engl.	H. Christensen & F. L. Apu 570 (K)
2. *S. borneensis* Engl. & K. Krause	Sumbing Jipin 113797 (K)
3. *S. coriaceus* Engl.	P. Chai S33827 (KEW)
4. *S. crassipes* Engl.	Nur 34331
5. *S. curranii* Engl. & K. Krause	D. Le Roy Topping 1596 (K)
6. *S. geniculatus* Engl.	Fedilis Krispinus 95887 (K)
7. *S. glaucescens* (Engl. & K. Krause) Alderw.	B. L. Burtt & A. M. Martin B4972 (E)
8. *S. hederaceus* Miq.	T. Horsfield 245 (K)
9. *S. longipes* Engl.	Dyg. Awa & B. Lee S50974 (K)
10. *S. longistipitatus* Merr.	P. Castro & F. Melegrito 1345 (K)
11. *S. latifolius* M. Hotta	P. C. Boyce 351 (K)
12. *S. lucens* Bogner& P.C. Boyce	Hay *et al.* 9170 (UPM)
13. *S. perakensis* Hook. f.	Kunsler (Dr. King's collector) 5306 (K)
14. *S. pictus* Hassk.	J. Sumbing 103454 (K)
15. *S. rupestris* Ridl.	Richards 1679 (K)
16. *S. scortechinii* Hook. f.	Scortechini 370 (K)
17. *S. havilandii* Ridley	G.D. Haviland 2089 (KEW)

The habit of the stem was noted: lianas, creeper or epiphyte. Leaves, stem, root and inflorescences were examined. The three largest leaves on each herbarium specimen were chosen for examination. Petiole and lamina length and width were measured on the most accessible and complete leaf of each specimen to ensure that ratios comparing these measurements are accurate. Lamina morphology (texture and shape) and petiole morphology (geniculum and sheath) were recorded. The presence of any variegation was noted. The detail of lamina venation near the midrib was observed using a dissecting microscope. Material bearing inflorescences was selected and the pistil was observed using a dissecting microscope.

The micromorphological study was carried out using Scanning Electron Microscope (SEM) JEOL JSM-T20 SEM, operating at 20 kV. The anatomical study involved preparing microscope slides of the transverse section of the samples and examined under a light microscope. The process used for making permanent microscope slides followed the procedures described in O'Brien and McCully's (1981).

The same specimens were used for lamina surface micromorphological and anatomical studies. Samples for both examinations were taken from a standard central position, midway between the base and apex, of the lamina.

The numerical analyses used Multivariate Statistical Procedures (MVSP Plus Version 2.2) software (Kovach, 1995). The programmes used for the analyses were nearest neighbor cluster analysis and farthest neighbor cluster analysis. Gower general similarity coefficient (GGSc) was used to generate the similarity matrices. By using this coefficient, the absolute similarity is marked by the GGSc = 1.000.

RESULTS AND DISCUSSIONS

A total of 37 characters were derived from the study (Appendix 1), which are 24 morphological, five micromorphological (SEM studies) and eight anatomical characters. The character matrices are given in Appendix 2. Some of the quantitative characters that vary most in the data set are converted to logs for standardization. Standardization of the measurements ensures that they all have equal weight in the analyses and would not tend to dominate the analyses.

Figure 1 shows the dendrogram resulting from the farthest neighbor cluster analysis. Figure 2 shows the dendrogram resulting from the nearest neighbor cluster analysis. The absolute similarity is marked by GGSc = 1.000.

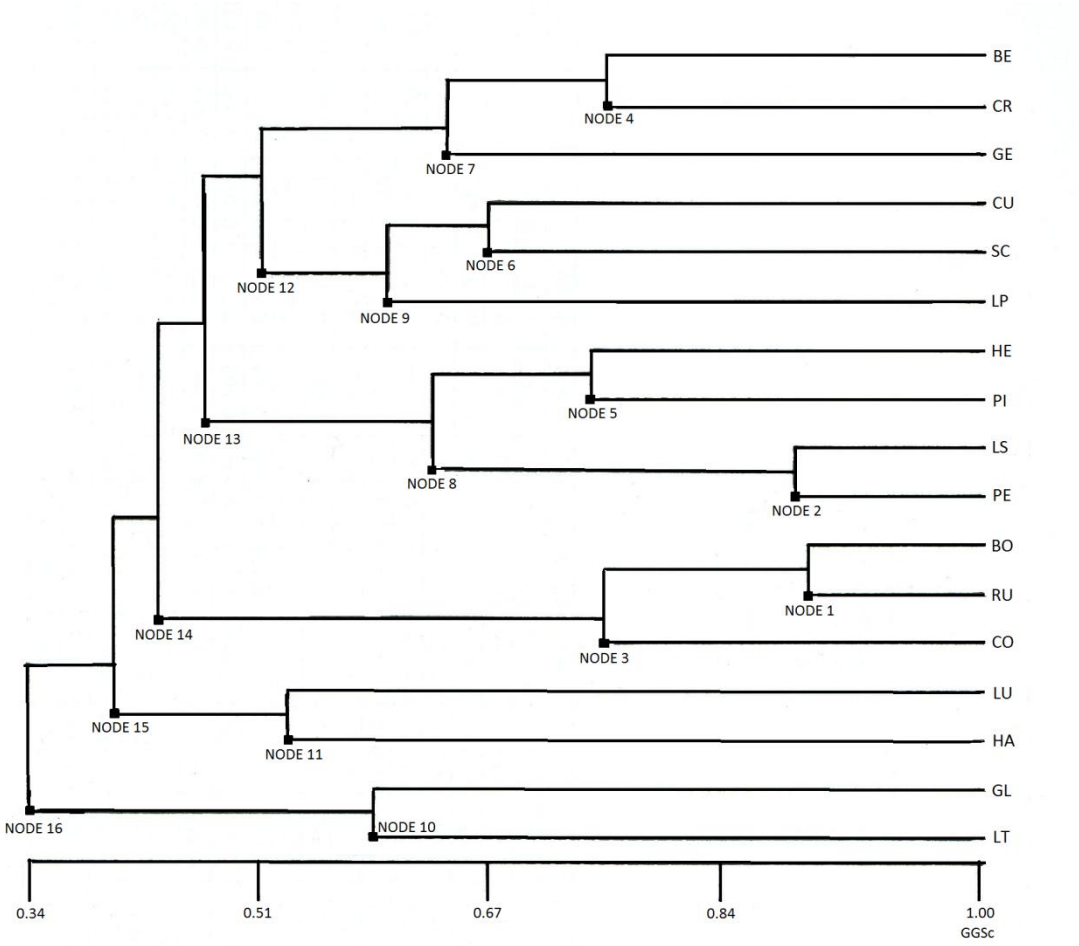
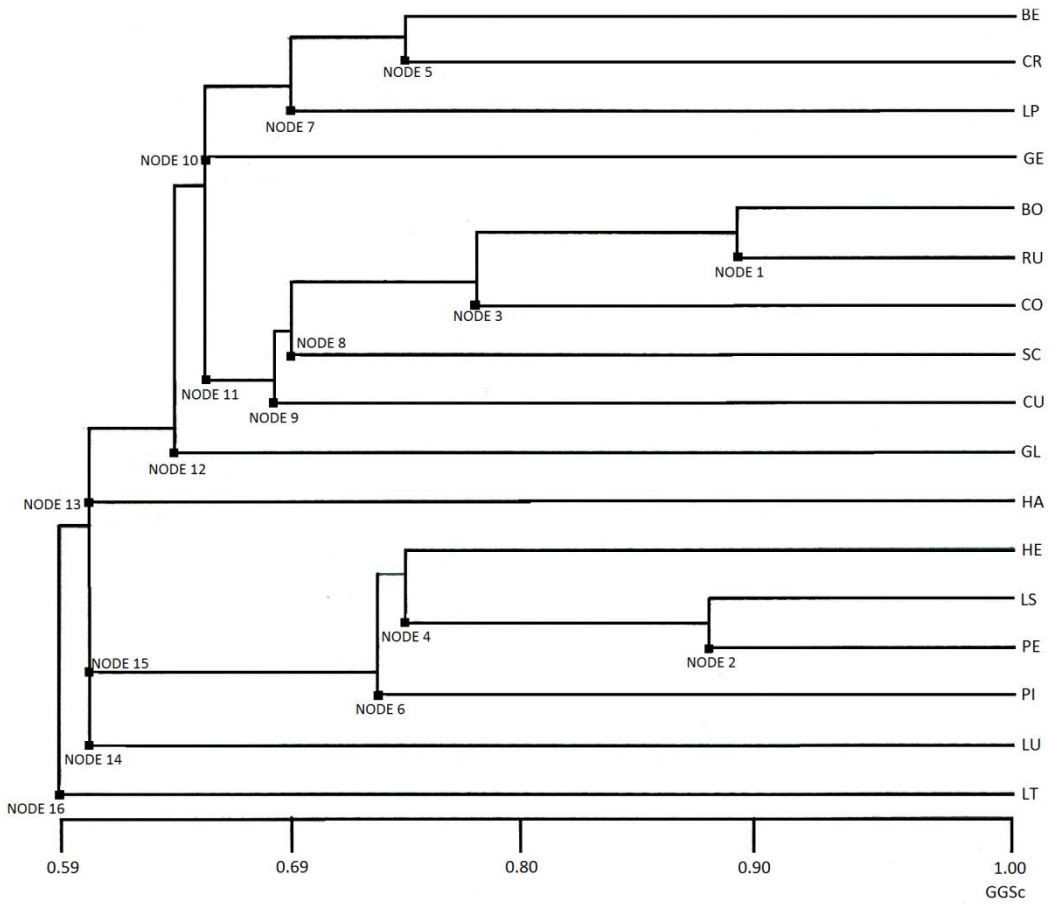


Figure 1: Dendrogram of 17 *Scindapsus* species resulting from the farthest neighbour cluster analysis.



Key:

Ch.	=	Character	HE	=	*Scindapsus hederaceus*
BE	=	*Scindapsus beccarii*	LT	=	*Scindapsus latifolius*
BO	=	*Scindapsus borneensis*	LP	=	*Scindapsus longipes*
CO	=	*Scindapsus coriaceus*	LS	=	*Scindapsus longistipitatus*
CR	=	*Scindapsus crassipes*	LU	=	*Scindapsus lucens*
CU	=	*Scindapsus curranii*	PE	=	*Scindapsus perakensis*
GE	=	*Scindapsus geniculatus*	PI	=	*Scindapsus pictus*
GL	=	*Scindapsus glaucescens*	RU	=	*Scindapsus rupestris*
HA	=	*Scindapsus havilandii*	SC	=	*Scindapsus scortechinii*

Figure 2: Dendrogram of 17 *Scindapsus* species resulting from the nearest neighbour cluster analysis.

Both of the dendrograms (Figure 1 and 2) show three constant clustered groups that are as follows:

1. *Scindapsus beccarii* and *S. crassipes*.
2. *Scindapsus hederaceus*, *S. pictus*, *S. perakensis* and *S. longistipitatus*.
3. *Scindapsus coriaceus*, *S. rupestris* and *S. borneensis*.

In farthest neighbour cluster analysis, *S. geniculatus* clustered to *S. crassipes* and *S. beccarii*. *Scindapsus geniculatus* and *S. crassipes* are creepers and mostly recorded from east Malaysia. *Scindapsus crassipes* is more similar to the epiphyte *S. beccarii* (GGSc = 0.741) compared to *S. geniculatus* (GGSc = 0.636). *Scindapsus crassipes* are first recognized by Engler in 1881 but in 1908 he recognized *S. crassipes* as a synonym to *S. beccarii* (Engler*et al*., 1908). Ridley (1905, 1925) also had difficulties in separating the vegetative morphology between *S. crassipes* and *S. beccarii* and recognized them as one species, *S. beccarii*.

This study shows that the epiphytic *S. beccarii* and the creeper *S. crassipes* are definitely different species. *Scindapsus beccarii* and *S. crassipes* are different not only in vegetative and floral morphology but also in micromorphological characters. *Scindapsus beccarii* has a yellow spathe and *S. crassipes* has a white spathe. Morphologically, *S. beccarii* has an elliptic lamina shape with a cuspidate or slightly acuminate lamina apex and the petiole sheath shape narrowed to an apical geniculum whereas *S. crassipes* has an obovate lamina shape with a blunt lamina apex and the petiole sheath of equal width up to the apical geniculum. Micromorphologically, *S. beccarii* has a non-striate abaxialcuticular surface whereas *S. crassipes* has a striate abaxialcuticular surface.

Scindapsus pictus clustered with *S. hederaceus*, *S. perakensis* and *S. longistipitatus*. *Scindapsus hederaceus* had a very high similarity to *S. perakensis* (GGSc = 0.746), followed by *S. pictus* (GGSc = 0.734) and *S. longistipitatus* (GGSc = 0.718). The lianas *S. perakensis* and *S. longistipitatus* have a very high similarity (GGSc = 0.870). Although the vegetative morphology of *S. perakensis* and *S. longistipitatus* are similar, the floral morphology and anatomy are different. *Scindapsus perakensis* has a sessile spadix with adaxial lamina epidermis cells enlarged whereas *S. longistipitatus* has a stipitate spadix with adaxial and abaxial lamina epidermis cells similar in size.

Scindapsus coriaceus, *S. rupestris* and *S. borneensis* form a constant cluster in the dendrograms. *Scindapsus coriaceus* and *S. borneensis* are both recorded only from east Malaysia and are often found on high altitude area. *Scindapsus rupestris* is recorded from Malaysia and living as a rheophyte (Mayo *et al*., 1997). *Scindapsus borneensis* has a high similarity to *S. rupesrtis* (GGSc = 0.886) compared to *S. coriaceus* (GGSc = 0.749). The vegetative morphology contributes the highest similarity between *S. rupestris* and *S. borneensis* and difficulties often arise in distinguishing the vegetative form of fresh and herbarium materials. However, the spathe colour can easily separate between *S. rupestris* and *S. borneensis*. *Scindapsus rupestris* has white spathe and *S. borneensis* has yellow spathe. In this study, only one character is not shared between *S. rupestris* and *S. borneensis*, which is the style width. *Scindapsus rupestris* has a style wider than the ovary and *S. borneensis* has an ovary wider than the style. The different inflorescence characters are probably due to different habitat. High altitudes may produce a white inflorescence with the ovary wider than style (*S. borneensis*) and low altitudes and rheophytic habitats may produce a yellow inflorescence with the style wider than the ovary (*S. rupestris*). However, plasticity in floral characters does not happen easily naturally compared to vegetative characters, unless in cultivation. Green house experiments and DNA analyses are essential in order to prove that *S. borneensis* and *S. rupestris* are separate species.

In farthest neighbour cluster analysis, *S. longipes* clustered with *S. scortechinii* and *S. curranii*. However, *S. scortechinii* was most similar to *S. coriaceus* (GGSc = 0.693). *Scindapsus curranii* was also most similar to *S. coriaceus* (GGSc = 0.691) and the east Malaysian *S. longipes* was most similar to *S. beccarii* (GGSc = 0.697).

Scindapsus lucens was most similar to *S. pictus* (GGSc = 0.611). Bogner and Boyce (1994) have highlighted a close relationship between *S. lucens* and *S. pictus* when they first

introduced *S. lucens*. The vegetative morphologies of these species were slightly similar at the juvenile phase. Both juvenile of *S. lucens* and *S. pictus* had a cordately laminae.

In nearest neighbour cluster analysis, *S. latifolius* appears to be most isolated species in the genus. The fibrous sheath texture in *S. latifolius* significantly distinguished *S. latifolius* from the rest of the *Scindapsus* species studied. *Scindapsus latifolius* was most similar to *S. glaucescens* (GGSc = 0.591). *Scindapsus aucescens* clustered with *S. latifolius* in farthest neighbour cluster analysis. *Scindapsus glaucescens* is endemic to Sarawak, whereas *S. latifolius* was found in Sarawak and Brunei.

Scindapsus havilandii clustered with *S. lucens* in farthest neighbour cluster analysis (GGSc = 0.525). Both of these species differ from the rest of *Scindapsus* species studied by having reticulate secondary veins. However, *S. havilandii* was most similar to *S. curranii* (GGSc = 0.612). Both *S. havilandii* and *S. curranii* differ from the rest of *Scindapsus* species studied by having a papery lamina. In this study, the qualitative character that significantly distinguished *S. havilandii* from the rest of the species is the number of inflorescences more than one. Thus, it is proposed here that *S. havilandii* is excluded from the genus *Scindapsus* and to be included in the genus *Rhaphidophora* as the vegetative and floral characters observed were more similar to the latter.

The overall similarity relationships between the 17 *Scindapsus* species of Malaysia are not significantly correlated with the habitat, growth habit and geographic distribution. The characters of the groups have a high similarity, especially *S. perakensis* and *S. longistipitatus*, and *S. rupestris* and *S. borneensis* are similar in vegetative morphological qualitative characters. The flower morphology and vegetative micromorphology and anatomical characters contributed most to distinguishing the species in these groups.

CONCLUSION

This study concluded that there are three constant clustered groups in the genus *Scindapsus* based on similarity in morphological and anatomical characters. These groups are: (1) *Scindapsus beccarii* and *S. crassipes*, (2) *S.hederaceus*, *S. pictus*, *S. perakensis* and *S. longistipitatus* and, (3) *S. coriaceus*, *S. rupestris* and *S. borneensis*. *Scindapsus havilandii* is proposed to be excluded from the genus *Scindapsus* and to be included in the genus *Rhaphidophora*.

Scindapsus borneensis and *S. rupestris* share a wealth of vegetative morphology characters. Therefore, wider investigations are required based on morphology, anatomy, embryology, palynology, ecology, physiology, cytology, genetics, etc. to prove the affinities of *S. borneensis* and *S. rupestris*.

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Appendix 1: Character coding of 17 *Scindapsus* species for numerical analyses.

Morphological characters

1. Growth habit : creepers (0), lianes (1), epiphytes (2).
2. Lamina shape: ovate/ovate oblong (0), elliptic (1), lanceolate/lanceolate falcate(2), obovate (3).
3. Lamina base : blunt (0), acute (1), cuneate (2), cordate (3).
4. Lamina apex : blunt (0), acute (1), cuspidate/acuminate (2).
5. Lamina texture : coriaceous (0), papery thin (1).
6. Lamina secondary lateral veins : parallel (0), reticulate (1).
7. Lamina minor veins: parallel (0), transverse/reticulate (1).
8. Sheath shape : narrowed to apical geniculum (0), equal width to apical geniculum (1).
9. Sheath texture: coriaceous (0), membranous (1), fibrous (2).
10. Spadix : sessile (0), stipitate (1).
11. Style width : style > ovary (0), style = ovary (1), ovary > style (2).
12. Stigma shape: round (0), elliptic (1).
13. Log mean lamina length :
14. Log mean lamina width :
15. Ratio of mean lamina length / mean lamina width :
16. Log mean petiole length :
17. Log mean peduncle length :
18. Log mean spadixlength :
19. Mean spadix thickness (cm) :
20. Log ratio mean spadix length / mean spadixthickness :
21. Log mean pistil height :
22. Log mean the widest of pistil :
23. Ratio mean pistil height / mean the widest of pistil :
24. Number of inflorescences : solitary (0), 2 or more 1 (1).

Micromorphological characters

25. Adaxialcuticularsurface : non-striate (0), striate (1).
26. Abaxialcuticularsurface : non-striate (0), striate (1).
27. Adaxialstomata : absent (0), present (1).
28. Adaxial epidermal cell shape : irregular (0), polygonal (1).

29. Abaxial epidermal cell shape : irregular (0), polygonal (1).

Anatomical characters

30. Adaxialmidrib : flat (0), grooved (1), convex (2).
31. Abaxialmidrib : flat (0), convex (1).
32. Lamina epidermal cell size :adaxial=abaxial (0), adaxial enlarged (1).
33. Lamina adaxial hypodermal layer : absent (0), present (1).
34. Lamina mesophyll druses : absent (0), present (1).
35. Lamina mesophyll raphides : absent (0), present (1).
36. Petiole druses : absent (0), present (1).
37. Petiole raphides : absent (0), present (1).

Appendix 2: Character matrices of 17 *Scindapsus* species for numerical analyses.

	Taxa																
Ch.	BE	BO	CO	CR	CU	GE	GL	HA	HE	LT	LP	LS	LU	PE	PI	RU	SC
1	2	0	0	0	1	0	0	0	1	0	1	1	0	1	0	0	1
2	1	2	2	3	2	2	2	2	2	2	0	2	0	2	2	2	1
3	0	1	1	0	0	2	2	2	2	0	0	0	3	0	0	1	0
4	2	2	2	0	2	1	2	2	1	1	2	2	2	2	2	2	1
5	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
7	1	0	0	1	0	1	0	1	0	0	1	0	1	0	0	0	0
8	0	0	0	1	0	0	0	0	1	0	0	1	1	1	1	0	0
9	0	0	0	0	1	0	1	1	0	2	0	0	0	0	0	0	0
10	0	0	0	0	0	1	0	0	0	1	0	1	1	0	0	0	0
11	1	2	1	1	1	0	1	0	1	0	2	2	1	2	1	1	1
12	0	1	1	0	1	0	0	0	1	1	0	1	1	1	1	1	0
13	1.4	1.2	1.1	1.6	1.2	1.6	1.7	1.4	1.2	1.7	1.1	1.5	1.0	1.4	1.1	1.3	1.1
14	1.0	0.5	0.5	1.1	0.8	0.9	1.3	0.8	0.8	1.4	0.9	1.0	0.9	0.8	0.9	0.4	0.8
15	2.3	5.1	4.5	3.1	2.6	5.3	2.6	4.4	2.4	1.9	1.8	3.4	1.4	3.5	1.5	7.8	2.2
16	1.4	1.4	1.0	1.2	0.9	1.4	1.5	1.2	1.0	1.7	1.3	1.2	0.6	1.1	0.2	1.0	1.0
17	1.0	0.9	1.0	1.1	1.0	0.5	1.0	0.4	0.7	1.0	0.3	1.3	0.7	1.0	0.2	0.7	0.7
18	0.8	0.3	0.9	0.9	0.6	0.8	1.4	0.6	0.5	1.4	0.9	1.0	0.4	1.1	0.5	0.2	0.5
19	2.0	0.5	1.3	3.0	0.9	1.5	4.0	1.0	0.6	2.2	1.2	1.5	1.0	2.5	0.6	0.3	0.6
20	3.5	4.4	6.2	2.7	5.0	4.7	6.2	3.8	5.0	10.9	6.7	6.0	2.7	5.0	5.3	5.0	5.3
21	0.7	0.6	0.3	0.5	0.5	0.5	0.7	0.0	0.6	0.9	0.7	0.8	0.3	0.6	0.6	0.5	0.2
22	0.4	0.4	0.0	0.2	0.6	0.3	0.3	0.4	0.8	0.4	0.2	0.9	0.5	0.8	0.8	0.3	0.2

23	2.1	1.4	2.0	1.8	0.8	1.5	2.6	0.4	0.6	2.9	3.0	0.7	0.7	0.7	0.7	1.6	1.0
24	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
26	1	1	1	0	0	1	1	0	0	1	0	0	0	0	0	1	1
27	0	0	1	0	1	1	0	1	0	0	0	0	1	0	1	0	1
28	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	0	0
39	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
30	2	0	0	2	0	2	2	0	2	1	0	2	0	2	1	0	0
31	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
32	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0
33	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	1	1
34	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
35	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
36	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
37	0	0	0	0	0	0	1	1	1	1	0	1	1	1	1	0	0

Key:

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