EFFECT OF VOLCANIC ERUPTIONS ON NEARBY COCONUT PALMS: WHY MOST LEAVES SNAP AT THE TIP OF PETIOLE

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ABSTRACT

The repeated eruptions during 1982 of Mt. Galunggung in West Java killed about one million coconut palms, apart from causing incalculable damage to other crops, agricultural land and buildings. Most of the coconuts killed were from an area within 5 km from the volcanic centre. Several other coconut palms standing at farther distances from Mt. Galunggung were partially damaged. A striking feature of such palms is the characteristic appearance of their crown that resembles a partially folded umbrella. This has resulted because most of the green leaves snap at the tip of the petiole, at a point where the leaflets begin to develop, and droop slantingly. The reason for snapping of the leaf at the petiole was investigated on tall and dwarf variety palms by slicing the entire leaf into 25 cm-long bits and recording their weights and dimensions. In terms of both weight and size, the tip of the petiole manifests some weakness, as a result of which, snapping takes place near this point when the lamina portion receives an unusual stress in the form of falling wet sand and ash from volcanic eruptions. Snapping of green leaves is also characteristic of coconut crowns affected by severe drought. Under continued desiccation, the petiole of green leaves loses much of its moisture and becomes flaccid, thus its strength is reduced, and hence allows itself to be broken at any point according to the nature and direction of prevailing wind. Observations recorded on several palms subjected to severe drought have revealed that snapping takes place anywhere throughout the length of the leaf, but more strikingly within the upper half of petiole. The leaves of an extremely small number of palms remained undamaged inspite of the several eruptions. Seeds from such palms will be collected for evolving a progeny that is likely to inherit stronger leaf characters.

RINGKASAN

Pengaruh letusan gunung berapi terhadap pohon kelapa di sekitarnya:

Kenapa kebanyakan daun patahnya pada ujung tangkai pelepah

Letusan Gunung Galunggung di Jawa Barat yang terjadi berulang kali selama tahun 1982, telah membinasakan kira-kira satu juta pohon kelapa, di samping tanaman-tanaman lainnya, tanah-tanah pertanian serta bangunan-bangunan yang tidak dapat diperkirakan. Kebanyakan pohon-pohon kelapa yang mati itu berada di daerah sekitar 5 km dari pusat letusan gunung tersebut. Beberapa pohon kelapa lainnya yang berada lebih jauh dari tempat tersebut kerusakannya hanya sebagian saja. Suatu kesan yang paling menarik dari pohon-pohon kelapa demikian, ialah bentuk mahkotanya yang khas merupakan payung setengah terkatup. Hal tersebut disebabkan karena kebanyakan daun-daun muda patah pada ujung tangkai pelepahnya, yaitu pada suatu titik di mana mula-mulanya anak daun berkembang, sehingga daun yang patah itu menggantung. Alasan patahnya daun pada tangkai pelepah telah diteliti pada kelapa dalam dan kelapa genjah dengan memotong seluruh pelepah daun menjadi potongan-potongan kecil, berukuran 25 cm dan mencatat berat serta dimensinya. Dipandang dari berat maupun dari ukurannya, maka ujung tangkai pelepah memperlihatkan beberapa kelemahan. Akibatnya daun patah pada titik tersebut bilamana bagian itu memikul beban terlalu berat dalam bentuk pasir dan debu basah dari letusan gunung yang melekat pada pelepah daun. Patahnya daun muda juga merupakan ciri khas pada tajuk kelapa yang ditimpa kekeringan yang hebat. Akibat dari keadaan kering terus-menerus, maka tangkai pelepah muda banyak kehilangan airnya dan menjadi lemah, kekuatannya berkurang dan seterusnya pelepah itu patah dengan sendirinya pada suatu titik menurut keadaan dan arah angin. Catatan pengamatan dari beberapa tanaman kelapa yang menderita kekeringan hebat telah memperli hatkan bahwa patahnya tangkai pelepah dapat terjadi di mana saja sepanjang tangkai pelepah, akan tetapi lebih menyolok pada pertengahan sebelah atas dari tangkai pelepah tersebut. Daun-daun dari sejumlah kecil pohon kelapa tidak mengalami kerusakan walaupun terjadi letusan beberapa kali. Biji-biji dari pohon tersebut dapat dikoleksi untuk mendapatkan keturunan yang mempunyai sifat daun yang kuat.

INTRODUCTION

The volcanic mountain, Galunggung, located at the eastern part of West Java Province, Indonesia erupted several times during mid-1982 causing great damage to millions of coconut palms, thousands of hectares of agricultural land including standing crops, fish ponds and numerous houses of many villages, thus bringing untold misery to the local inhabitants, and increasing the difficulties of the government for solving the problems. The first eruption of 1982 took place on April 5 which was followed by a further 35 major and over 300 minor eruptions upto the one on 20th September, 1982, which day happened to synchronise the inaugural function of a National Seminar that went to discuss on the risk management of the volcanic èruptions of Mt. Galunggung. The intensity and cumulative bad-effect could be guessed by knowing that the glowing clouds flowing to the upper reaches of Cikunir and Cibanjaran rivers deposited at the mountain summit approximately 20 million cubic metres of lava. Further, part of the ash which fell on the catchment areas of three rivers located near the volcano were estimated at for Cimanuk rivers 29 million cubic metre of lava, for Ciwulon river 17 million cubic metre and for Citanduy river 15 million cubic metres. Rock fragments were found ejected upto a distance of 6 km away from the volcanic crater (HADJISAROSA, 1982).

The activities of the Industrial Crops Research Institute have increased also because of the eruptions of Mt. Galunggung as well as Mt. Soputan of North Sulawesi Province, both being located in areas important for industrial crops. The following are the priorities: (1) assessing the extent of damage caused by the eruptions to industrial crops, particularly to coconut and clove; (2) understanding the changes brought about to the soil by the heavy deposits of sand, ash and dust whose compositions are not yet known fully, and ameliorating the bad effects; (3) recommending measures for the rapid rehabilitation of the area, and (4) implementing the measures by making available appropriate planting materials and other inputs to guarantee re-establishment of productive industrial crops within reasonably a short time (ANON, 1982).

Two of us (AH and TAD) visited during the first week of August some of the volcano-affected areas near Mt. Galunggung and in and around Tasikmalaya, Garut and Pangandaran

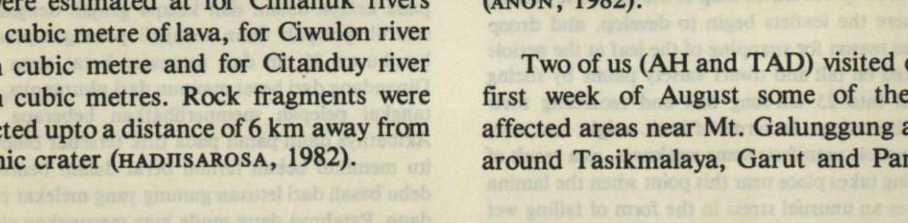

Figure 1. View of coconut palms totally killed by volcanic eruptions of Mt. Galunggung, West Java

Gambar 1. Pemandangan pohon-pohon kelapa yang mati oleh letusan gunung Galunggung, Jawa Barat

Figure 2. Closer view of coconut palms standing within 5 km from Mt. Galunggung which are about to die

Gambar 2. Tanaman kelapa yang hampir mati sampai sejauh 5 km dari G. Galunggung

Figure 3. Snapping of leaves at the tip of petiole is clearly seen in this palm growing near Garut

Gambar 3. Patahnya daun pada ujung tangkai pelepah jelas sekali terlihat pada tanaman kelapa ini tumbuh dekat Garut

and made preliminary investigations on the extent of damage done to coconut, cloves and other industrial crops. Davis made further visits to the area. About one million coconut palms standing within 5 km radius from the volcanic centre have been killed (Figs. 1 & 2) or irrecoverably damaged by the falling of hot sand and dust, flowing of hot lava between them, and perhaps due to the poisonous and toxic effects of the volcanic ash and dust. Also there are about three million coconuts standing in areas extending upto 18 km from the volcanic centre which stand partially damaged, some of which are likely to die within a couple of months from receiving the injury. The eruptions spread toxic levels of aluminium salts (20.9% of total deposits) and ferrous salts (7.27%) around coconut palms in large areas. With the first rains, the palms were compelled to absorb a high concentration of such salts through the roots, as a consequence, the leaves turned bronzing. This would result in the death of more palms. PANDALAI *et al.* (1954) also reported on the death of many coconut palms in Central Kerala, India due to the absorption of excessive quantities of ferrous iron and soluble aluminium dredged out from deeper layers of soil while constructing the Thottapally spillway. The most striking feature of the affected palms is the characteristic way the green leaves snap and droop. Most of the leaves are broken almost at the tip of the petiole at a point where the leaflets start developing. On account of this, the crown takes the form of a partially folded umbrella (Fig. 2).

Even the leaves of young palms are similarly damaged (Figs. 3 & 4). Our curiosity to find a reason for such a snapping of leaves has resulted in the present investigation.

Figure 4. A young palm near Tasikmalaya with most leaves drooping

Gambar 4. Sebatang kelapa dekat Tasikmalaya daunnya menggantung

MATERIALS AND METHODS

Three mature leaves each from six tall variety palms, and six mature leaves each of six Nias yellow dwarf palms growing at the coconut seed garden of the Manado Research Institute for Industrial Crops were ripped off carefully from the base with a sharp chopper. Only complete leaves where none of the leaflets was damaged were selected. The total length of the leaf was measured and the number of leaflets for each linear half recorded. The leaf was then marked at 25 cm intervals from the base and sawn at each mark. The following weights and measurements were recorded for each of the 25 cm-long bits.

(1) Weight of bit including leaflets where present;
(2) Weight of bit after removing leaflets where present;
(3) Maximum thickness of petiole/rachis for each bit;
(4) Maximum width of bit on the lower surface; and
(5) Maximum width of bit on the upper surface.

Separate graphs were prepared for the tall and dwarf palms with the data obtained on the weights of pieces, one with the leaflets on and

Table 1. Weights of 25 cm long pieces of leaves of dwarf and tall coconut palms
Tabel 1. Berat dari 25 cm potongan-potongan pelepah daun kelapa genjah dan kelapa dalam

25-cm pieces of leaf (from the base of leaf)	Nias Yellow Dwarf		Tall Variety	
	Mean weight (gram) for 36 leaves		Mean weight (gram) for 21 leaves	
	With leaflets	Without leaflets	With leaflets	Without leaflets
1	1,276.83		2,545.00	
2	669.25		1,771.67	
3	434.83		1,336.67	
4	329.61		1,020.33	
5	265.31	234.00	831.67	
6	272.72	232.10	718.33	
7	325.44	201.31	631.67	
8	347.19	173.14	585.00	
9	343.28	146.42	615.00	540.00
10	329.83	122.50	618.33	485.00
11	314.03	103.81	628.33	440.00
12	291.67	83.72	621.67	398.33
13	266.08	64.81	611.67	358.33
14	217.86	46.56	601.67	311.67
15	171.22	31.58	618.33	281.67
16	117.31	20.14	596.67	251.67
17	76.78	11.39	543.33	213.33
18	40.29	5.59	511.67	181.67
19	13.33	1.93	448.33	155.00
20	6.00	1.00	403.33	111.67
21			333.33	88.33
22			298.33	70.00
23			235.00	46.67
24			173.33	31.67
25			135.00	16.67
26			80.00	3.00
27			25.00	1.00

developing. The weights of subsequent bits bearing leaflets increase, but gradually decline from about half the length of the lamina portion of the leaf. This clearly indicates the presence of a bottleneck at the tip of the petiole which portion has been the snapping point for most leaves of the volcano-affected palms. The tip of the petiole is normally under strain to support the weight of the lamina and hold it in position. So, when additional weight is added on to the lamina, the leaf snaps at the thinnest (and obviously the weakest) region of the petiole. When the leaflets are removed, the left-over rachis shows more or less a normal distribution of weights which decreases in keeping with the decreasing trend of the weight of petiole.

The volcanic eruptions of Mt. Galunggung emitted sand and ash in a wet condition unlike such emitions from the volcano at Mt. Soputan in North Sulawesi which were rather dry. Hence they filtered through between coconut leaflets. Thus, most of the coconut palms around Soputan mountain escaped snapping of leaves. The wet deposit on coconut leaves in West Java become thicker and thicker, and when the weight of such deposits went beyond the holding capacity of the leaf, it broke at the weakest spot, that is, at the tip of the petiole. Fig. 5 shows portion of

Figure 7. Young cocoa plant at Pangandaran having been severely damaged by falling of wet sand-dust-ash mixture from the volcano

Gambar 7. Tanaman coklat muda usia mendapat kerusakan berat oleh endapan campuran pasir-debu-abu basah dari gunung berapi

leaf of palm standing at the PTP XIII Estate at Pangandaran, a place about 70 km away from Galunggung which received between 1 and 3 cm layer of wet sand-ash mixture. At this rate, palms standing near Tasikmalaya and Ciamis should have been loaded with over 10 kg sand-ash mixture on each leaf which load the coconut lamina is not strong enough to receive and hold at the normal position. As suggested by Dr. D.B. Reddy, FAO Representative at Jakarta, we tested the load-holding capacity of leaves of ten Nias dwarf palms. Five of them snapped at loads ranging from 5.5 kg to 10.0 kg, while the rest snapped at loads between 11.8 kg and 16.1 kg. Over-mature leaves snapped more easily than the turgid younger ones. It may thus be presumed that the leaves of palms affected by volcanic deposits were partially affected by the heat and poisonous effect of the deposits during the first one or more eruptions. Such weakened leaves could snap even when they received deposits as low as 6 kg. At Pangandaran, about one thousand coconut palms were partially damaged by the deposition of volcanic materials on the leaves. But the damage to cocoa plants at this Estate is even more serious, because presumably the cocoa leaves can hold more materials. Due to the weight of deposits, many cocoa plants have their stems broken (Fig. 7).

With the other set of data on the width of lower petiole/rachis and the thickness of petiole/rachis, graphs were prepared. While the thickness of the petiole/rachis remains almost constant throughout the length, the width rapidly gets narrowed from the first bit which is the widest. At the end of the petiole (of tall palm), its width is only about 25% of what it is at the starting point. The ratio of width (lower surface) to thickness of petiole/rachis is plotted into a graph and shown in Fig. 8. Fig. 9 also reveals this clearly. Coconut leaf starts developing as a tube. Even when the leaf emerges as fully developed, the petiolar portion continues to be tubular because the sheathing base links both the margins of the petiole. The lowest portion of the petiole covers about three-fourths of the stem which is cylindrical. This curved nature of

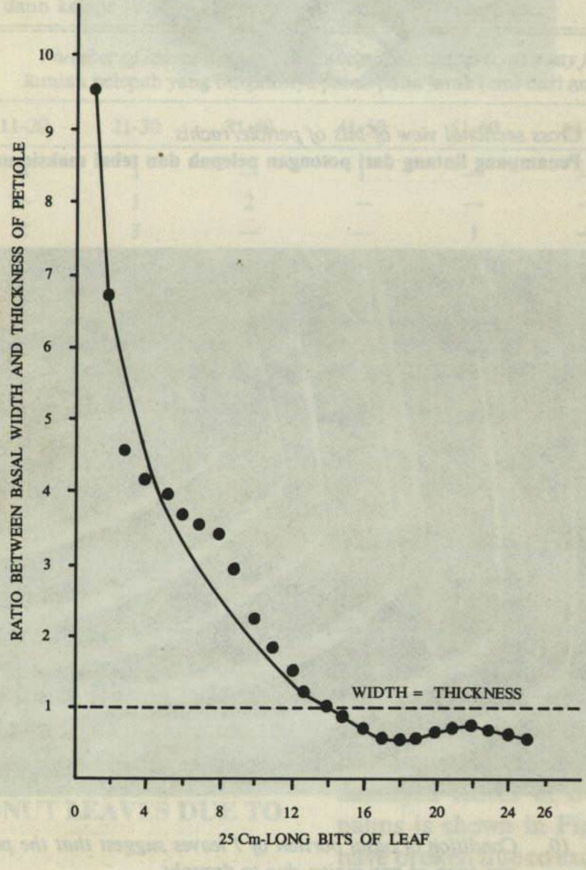

Figure 8. Graph showing the width and thickness of pieces of petiole/rachis
Gambar 8. Grafik menunjukkan lebar dan ketebalan dari potongan-potongan pelepah

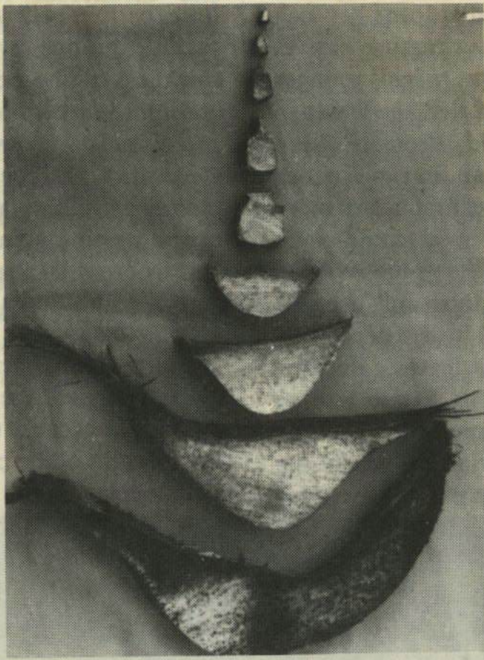

Figure 9. Cross sectional view of bits of petiole/rachis
Gambar 9. Penampang lintang dari potongan pelepah dán tebal maksimumnya

Figure 10. Condition of basal portion of 7 leaves suggest that the petiole can snap at any region due to drought
Gambar 10. Bagian pangkal dari 7 pelepah daun bisa patah dimana saja diakibat oleh kekeringan

the petiole offers good strength as it will not allow the petiole to bend easily. But as the width gets narrowed down, its curvature also gets reduced, and at the end of the petiole it is almost flat and measures only twice as broad as its thickness. Thus, the tip of the petiole is the weakest of the entire petiole. It is here the leaf is seen snapping more frequently. The rachis does not easily snap because of its girder-like appearance which gives greater strength. Here, the thickness of rachis is almost equal to or greater than its width. Such a mechanism compensates for the lack of a curvature on the rachis. A strong curvature of the rachis will restrict the free movement of the lamina which is essential to receive maximum solar energy.

POSSIBLE RESISTANCE AGAINST SNAPPING OF LEAVES

Even in areas where coconut palms were severely damaged, we could come across stray cases of exceptional palms whose leaves did not show any snapping inspite of the numerous volcanic eruptions. One could suspect the leaves of such palms possessing extra-ordinary strength and/or different anatomical structure. Such a leaf-character requires to be preserved for further studies through breeding for possible evolution of strain that would possess stronger leaves. Therefore, it is proposed to identify some of these palms for the collection of seed material later on. Right now the palms have shed most of

Table 2. Snapping of leaves of Nias dwarf coconut due to drought
Tabel 2. Pelepah-pelepah daun kelapa varietas genjah Nias patah akibat kekeringan

Tree Pohon	*Number of leaves whose petiole snap at distances (cm) away from leaflets* Jumlah pelepah yang tangkainya patah pada jarak (cm) dari anak-anak daun								
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	Total
1	—	4	1	—	1	—	—	—	6
2	—	—	1	2	–	—	—	1	4
3	3	2	3	—	—	1	—	—	9
4	—	1	2	2	1	1	—	—	7
5	—	—	2	—	1	—	—	1	4
6	—	—	1	3	—	1	—	—	5
7	1	—	—	2	—	—	—	—	3
8	1	2	—	—	—	2	—	—	5
9	—	1	2	1	2	—	—	—	6
10	—	—	2	—	—	1	1	—	4
11	1	2	—	—	—	1	—	—	4
12	1	1	1	1	—	—	—	—	4
13	2	—	2	2	1	—	—	1	8
14	1	2	3	2	2	—	—	2	12
Total	10	15	20	15	8	7	1	5	81

their buttons and young fruits. During 1983, the fruit yield of the surviving palms is expected to be very poor.

SNAPPING OF COCONUT LEAVES DUE TO SEVERE DROUGHT

Under prolonged drought, palms of the dwarf variety, the hybrids between dwarf and tall varieties, as well as the tall variety show different degrees of the adverse effect by possessing many dry and or broken leaves. The severely damaged leaves of dwarf x tall hybrid young palms is shown in Fig. 11. Many leaves which have broken due to excessive drought at the seed garden at Manado were pulled down and the position of snapping of each leaf recorded.

Figure 11. Damage due to volcanic deposits (left) compared with that caused by severe drought (right)
Gambar 11. Kerusakan oleh abu letusan gunung berapi (kiri) dibandingkan dengan kerusakan oleh kekeringan yang luar biasa

Figure 10 shows the petiolar portion of 7 leaves that has broken at various distances from their tip. Apart from this, data on 384 young palms of the tall variety which have shown severe drying of leaves due to drought were also recorded from the Kima Atas Experimental Farm near Manado. Those on 14 Nias dwarf palms on the nature of snapping of leaves due to drought are given in Table 2. The pattern of snapping of petiole was found to be similar in all the three varieties (tall, dwarf and D x T hybrids).

The data in Table 2 clearly show that under severe drought, the leaf snaps at any point on the petiole, but it takes place mostly within about half the distance from the tip. The intensity of wind also may change the pattern of snapping. Many dry or semi dry leaves are pulled down from their attachment with the stem during strongwind. Thus, the nature of snapping of leaves caused by volcanic deposits and those resulting from severe drought differs (Fig. 11).

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Indeks luas daun pada varietas lainnya telah dilakukan pengukuran. Dari setiap varietas diambil contoh satu tanaman, masing-masing diambil 30 daun pada cabang buah yang relatif homogen dan diharapkan luasnya mencapai maksimum. Contoh daun tersebut diambil pada waktu yang sama pada ketinggian 1 m di atas tanah.

Pada setiap contoh daun dihitung panjang (P cm), lebar maksimum (Q cm) dan luas daun (LD) dengan metoda cetak biru seperti yang dikemukakan oleh SOESENO, HARRAN dan PRAWIRANATA (1978). Indeks penghitungan luas daun (k) besarnya sama dengan LD/PQ.

Model linear aditif untuk setiap indeks penghitungan luas daun adalah:

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij}, \quad i = 1,2 \ldots\ldots\ldots 8$$
$$j = 1,2 \ldots\ldots\ldots 30$$
$$\varepsilon_{ij} \sim N(0.6^2).$$

Y_{ij} = nilai k dari daun ke-j pada varietas ke-i

μ = nilai tengah umum

τ_i = pengaruh varietas ke-i

ε_{ij} = pengaruh galat.

Untuk menduga kebaikan nilai k yang diperoleh digunakan selang kepercayaan. Makin sempit selang kepercayaan, makin baik nilai k yang diduga. Selang kepercayaan 95% bagi k untuk keseluruhan varietas adalah:

$$\bar{\bar{y}}_{ij} - \tau_{0.025}\, \hat{\sigma}_{\bar{\bar{y}}_{ij}} \leqslant k \leqslant \bar{\bar{y}}_{ij} + \tau_{0.025}\, \hat{\sigma}_{\bar{\bar{y}}_{ij}}$$

$\tau_{0.025}$ = nilai tabel τ

$\hat{\sigma}_{\bar{\bar{y}}_{ij}}$ = galat baku bagi $\bar{\bar{y}}_{ij}$

HASIL DAN PEMBAHASAN

Indeks penghitungan luas daun yang diperoleh untuk setiap varietas beserta galat bakunya disajikan pada Tabel 1. Ternyata nilai tersebut tidak berbeda jauh dengan nilai k yang diperoleh oleh I WAYAN DIPTA (1982).

Menurut SUSENO, *et al.* (1978) nilai k berbeda menurut bentuk daun dan bentuk daun dipengaruhi oleh varietas, status hara, stadia tumbuh dan umur daun. Status nutrisi, stadia tumbuh dan umur daun dapat dianggap sama, karena mendapat perlakuan yang sama, oleh sebab itu pada penelitian ini hanya varietas yang dibedakan.

Tabel 1. Nilai k pada setiap varietas lada dan galat bakunya
Table 1. k values for each pepper variety and their standard errors

Varietas *Variety*	k	Galat baku *Standard error*
Merapin	0.7280	0.0519
Minyak Aceh	0.7000	0.0284
Pulau Laut B.	0.7280	0.0509
Lampung Batavia	0.7530	0.0372
Cheriakaniakadan	0.7080	0.0505
Belantung	0.7480	0.0485
Bulok Belantung Lampung	0.6700	0.0333
Bangkayang Kalimantan Barat	0.6800	0.0332

Pada penelitian terdahulu galat bakunya lebih kecil karena banyak faktor yang dibedakan di dalamnya yaitu pohon, bagian pohon dan cabang sehingga mengakibatkan dugaan ragamnya lebih kecil. Sedangkan pada penelitian ini hanya daun bagian bawah saja yang diambil karena diharapkan akan mencapai luas maksimum. Apabila terjadi keragaman nilai k antar pohon maupun cabang maka kesimpulan tidak berlaku umum, tetapi harus dibedakan antar cabang maupun pohon.

Berdasarkan uji F pada model yang digunakan ternyata tidak ada keragaman indeks penghitungan luas daun antar varietas, oleh sebab itu nilai k yang diperoleh secara keseluruhan dapat berlaku untuk kedelapan varietas lada. Nilai k tersebut adalah 0.7144 dengan galat baku 0.0428 dan koefisien keragaman 32.83%. Selang kepercayaan 95% bagi k adalah (0.6305; 0.7983). Dengan

Tabel 2. Rataan luas daun setiap varietas lada
Table 2. The average leaf area for each pepper variety

Varietas *Variety*	Luas daun (cm^2) *Leaf area* (cm^2)	Varietas *Variety*	Luas daun (cm^2) *Leaf area* (cm^2)
Merapin	8.55	Cheriakaniakadan	78.25
Minyak Aceh	32.58	Belantung	32.99
Pulau Laut B	57.09	Bulok Belantung Lampung	29.07
Lampung Batavia	40.98	Bengkayang Kalimantan Barat	35.09

diperolehnya nilai k yang demikian berarti perbandingan antara luas daun dengan panjang kali lebar untuk kedelapan varietas adalah sama, walaupun rataan luas daun antar varietas sangat bervariasi seperti pada Tabel 2.

Keuntungan yang diperoleh dengan k yang relatif homogen antar varietas adalah pengukuran luas daun. Dengan demikian dalam penggunaan nilai indeks, peneliti cukup mengingat satu nilai k saja tanpa memperhatikan varietas.

KESIMPULAN

Indeks penghitungan luas daun lada untuk daun pada bagian bawah tidak beragam antar delapan varietas yang diteliti. Nilai indeks tersebut secara keseluruhan adalah 0.7144 dengan galat baku 0.0428 dan selang kepercayaan (0.6305; 0.7983).

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