Validation method for assessing intensity of mistletoe infestation in teak

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Abstract. Occurrences of mistletoe infestations fluctuate depending on the environment and the biodiversity status, which includes anthropogenic factors. Recently, we have observed a potential hemiparasite in a teak clonal seed orchard located in Padangan, Central Java that caused a significant decrease in fruit (drupe) production. Almost one-third (1/3) of the existing trees were affected. The dead teak clones reduced the value of the clonal seed orchard as the ex-situ genetic resources conservation. Details on the use of the assessment method for assessing the intensity of infestation have not been validated, although results of preliminary assessment were available. The objective of this study was to validate the assessment method for the intensity of mistletoe infestation using the modified TMR-8 class rating. The validation was carried out based on the results of the Spearman correlation coefficient for the rating (numbers of mistletoes per host teak) and ANOVA for sub-rating (intensity of infected branches). The results showed that numbers of mistletoes grown on an individual teak tree was significantly affected by different classes of tree diameter, crown leaf ratio (LCR) and crown diameter. Besides, the crown diameter showed significant levels of difference on mistletoes infestation.

1. Introduction
During the growth process, teak trees experience various disturbances. Among those disturbances are pests and diseases, which reduce the quantity and quality of timber in teak plantation as well as fruit production in the Clonal Seed Orchard (CSO) in the working areas of Perhutani. Common pests in teak plantation include inger-inger (Neotermes tectonae), oleng-oleng (Duomitus ceramicus), weevils (Araecerus fasciculatus), mealybugs/cabuk (Pseudococcus), forest grasshoppers, termites, uret (Lepidiota stigma) and cancer in stem/branch [1,2]. A new threat, however, is recently observed in Padangan Clonal Seed Orchard (Padangan CSO) of Perum Perhutani, i.e. hemiparasite plant causing a decrease in teak fruit production in many teak clones. Padangan CSO is among the important sources of quality teak seed to support the improved teak planting program. Padangan CSO provides the seeds for Perhutani Jati Plus program. The seeds are produced using a vegetative propagation technique (cutting and tissue culture methods) and a generative propagation technique [3]. The Center of Research and Development of Perhutani Cepu produces two best clones...
of teak seeds i.e. PHT I and PHT II; and runs the development of two other clones i.e. PHT III and PHT IV [4].

There were 17,338 teak trees (almost ) of the existing trees infested by mistletoe and 48 teak trees of those trees were dead in Padangan CSO [5]. These situations reduced the value of genetic resources. It was predicted that a decline in teak fruit and seed production might affect the annual teak fruit production by ±8 tons/year. Flower and fruit production is affected by environmental factors such as site soil fertility, wind velocity fluctuations, wind directional changes, animal pollinators, pests and diseases infestation and corporate governance practices [6]. Mistletoe as hemiparasite is among diseases causing infestation in teak trees.

Efforts to reduce the level of infestation and the spread of mistletoes on teak trees are urgently required. The appropriate methods used should be immediate, effective, focused and low-cost involving mechanical, physical, silvicultural techniques, which include mixed cropping, biocontrol and chemicals.

It is important to implement a thorough and comprehensive method to assess the intensity of mistletoe infestation as one of the efforts included in the mistletoe control program. The characteristics of the infestation patterns of the mistletoe are among pertinent information to obtain in controlling the mistletoe. Mistletoe biological data should be used to develop a program to manage and control mistletoe infestation [7].

At present, research database mainly concerns on the nature of biological characterization of the mistletoe infestation. Research database on hemiparasite infesting forestry plants in Indonesia are rarely found. Basic data, data monitoring and evaluation from studied and applied research on mistletoe, however, are needed as a guideline/reference.

Previously some studies regarding the assessment method for the infestation of the mistletoe, especially on host of broadleaf tree species i.e [8] have grouped dominance or codominance of trees of *Pinus oocarpa* Schiede, which have infected the mistletoe of *Psittacanthus angustifolius* Kuijt in True mistletoe rating (TMR) 3-class. It consisted of class 0 of no infection, class 2 of its moderate, class 4 of its severe. [9] has proposed TMR 5-class but differently added point if one and more mistletoe was infected on stem of host tree.

The objective of this study was to validate the assessment method for mistletoe infestation intensity using modified TMR-8 class rating.

2. Method

2.1. Research site

This research was conducted at the Padangan CSO of Perum Perhutani blocks of teak trees. Observation Sample Plot (OSP) and Observation Measurement Plot (OMP) were established (n = 4 units) to well represent the CSO trees having several levels of infestation i.e. light, moderate, severe and no infestation (control). The study was conducted from May until October 2014.

2.2. Preliminary research

The distribution of mistletoe infestation in Padangan CSO was classified as: I (> 100 trees infected), II (50-100 trees infected) and III (<50 trees infected) [5]. In this study, a preliminary assessment was conducted based on a map of the intensity of the mistletoe infestation (1 : 18 000 scale) and field observation. The field observation was carried out in the OMP having size of 50 m x 50 m. Growth spacing applied in CSO was 10 m x 10 m and maximum trees were possible in one OMP of about 25 trees. The intensity of mistletoe infestation was determined based on the presence of mistletoe on an individual tree grown in the OMP area. The levels of infestation were determined as light (0-0.33) of (1-8) trees; moderate (0.33-0.67) of (9-16) trees; severe (0.67-1.00) of (17-25) trees; with a tolerance limit of 2 trees for each criterion. This classification was also applied in other study [10].
2.3. **Research implementation**

2.3.1. **Establishing OSP and OMP.** Observation Sample Plot (OSP) is a unit of homogeneous trees and land designed on the basis of several factors that are considered to be uniform on overall observations of the site conditions [11,12].

Observations conducted were toward types of teak trees infected by mistletoes and also on the intensity of mistletoe infestation. The intensity of mistletoe infestation varied and was classified as class 0 (control), class 1 (light), class 2 (moderate) and class 3 (high). The environmental conditions were relatively uniform i.e. climate type and soil type. If the uniformity could not be obtained within the OMP in a compact area inside its related OSP, then the OMP could be spread out within its OSP. Inside every OSP, four OMPs were established having size of 50 m x 50 m. The four OMPs were functioned as replications. The location of OMP was randomly determined. The formation of OSP and OMP were based on CRC (Collaborative Research Center) 990 guidelines [13]. Several modifications have been carried out due to field condition and status of mistletoe infestation. The modifications changed the size of sub-OMP from 5 x 5 m into 10 x 10 m, in accordance with growth spacing applied in CSO. There was no treatment conducted in the OMP. Inside the OMP, five sub-OMPs were established with a size of 10 x 10 m. The list of infested teak trees was created prior to establishment of sub-OMP to be functioned as sub-sample [14].

2.3.2. **Assessment procedure using modified TMR - 8 class rating** [10]. The criteria for determining the modified TMR-8 class rating (scale 0-7) were illustrated in the flow diagram (figure 1) and the details of the calculation of TMR scale were set out in table 1.

2.3.3. **Measured parameters and data analysis.** Measured parameters were the height, the tree diameter breast height (DBH), the crown diameter, the intensity of mistletoes infestation [16, 17, 18] and the levels of infected branches/twigs. Bartlett’s test was carried out periodically to determine the significance of differences in infestation intensity (value of TMR) toward the dimension of teak trees. The parameters measured to determine the dimension of teak trees were the tree diameter, basal area, leaf crown ratio (LCR), ratio of canopy height to the total height of the tree, the bole height, the crown diameter and the ratio of the total height to diameter (TT/D). If the result of the Bartlett’s test indicated that the data were homogenous, then the data were analyzed using the ANOVA followed by Duncan test, using SAS version 9.4 [19]. Further relationship analysis of the dimension of the tree (diameter, leaf crown ratio/LCR, crown diameter) against the mistletoe prevalence, the TMR and the TMI was carried out using the Spearman correlation. The difference of infestation intensity and the percentage of a dead bud toward the intensity of different infestations were tested using ANOVA and DMRT.
**Explanation:**

DMR = dwarf mistletoe rating; TMR = true mistletoe rating; A = top part of canopy; AA = top canopy of top sub-canopy; AT = Top canopy of sub-middle part; AB = top canopy of sub-lower part; T = middle part of canopy; B = lower part of canopy.
Table 1. Detail of modified TMR-8 class rating in teak stand (this study).

| Class rating | TMR (rating; sub-rating)\(^a\) | Infestation condition\(^b\) | Infestation criteria |
|--------------|---------------------------------|-----------------------------|----------------------|
|              |                                 | (A, B, C)                   | Qualitative          |
|              |                                 |                             | Quantitative         |
| 0            | 0                               | 0 + 0 + 0                   | No infestation       |
| 1            | 1+(0.5, 1); TMR 0.1–2.0         | (A, B, C)                   | Rather light         |
|              |                                 |                             | Light infestation    |
|              |                                  |                             | (TMR) = 0.1–3.0      |
| 2            | 2+(0.5, 1); TMR 2.1–3.0         | (A, B, C)                   | Light               |
| 3            | 3+(0.5, 1); TMR 3.1–4.0         | (A, B, C)                   | Rather moderate      |
|              |                                  |                             | Moderate infestation |
|              |                                  |                             | (TMR) = 3.1–5.0      |
| 4            | 4+(0.5, 1); TMR 4.1–5.0         | (A, B, C)                   | Moderate             |
| 5            | 5+(0.5, 1); TMR 5.1–6.0         | (A, B, C)                   | Rather severe        |
|              |                                  |                             | Severe infestation   |
|              |                                  |                             | (TMR) = 5.1–7.0      |
| 6            | 6+(0.5, 1); TMR 6.1–7.0         | (A, B, C)                   | Severe               |
| 7            | >7+(0.5, 1); TMR >7.0           | (A, B, C)                   | Very severe          |
|              |                                  |                             | Extremely very severe|
|              |                                  |                             | infestation (TMR) ≥ 7.0 |

\(^a\)Scale Rating of TMR = Rating \[\sum \text{mistletoe at part of canopy + scale of branch intensity is infected}\]; sub-rating (0.5) if the intensity of branch number is infected with mistletoe (stem free branch) < 50%, sub-rating (1.0) if the intensity of infected branch ≥ 50%.

\(^b\)A = Location of canopy where mistletoes were found (top, middle, lower canopy); B = species of mistletoes (D. pentandra, M. tetragonus, V. articulatum as hyper parasite, species of other mistletoes), various size of mistletoes (big, moderate, small), levels of mistletoes growth (young, middle, old); C = severity: 0 = healthy, 1 = dieback (mp) 0-10%, 2 = mp 10-20%, 3 = mp 20-30%, 4 = mp 30-40%, 5 = mp 40-50%, 6 = mp 50-60%, 7 = mp 60-70%, 8 = mp 70-80%, 9 = mp 80-90%, 10 = mp 90-100% [13]; (Supriyanto 25 July 2016, personal communication).

3 Results and Discussion

3.1 Validation method for assessing mistletoe infestation intensity

3.1.1. Rating: numbers of mistletoes. The performed Bartlett’s test displayed that all of the data of the measured parameters were homogenous, permitting ANOVA and other statistical tests to be conducted using the original data obtained from the field.

The results of ANOVA showed that the intensity of various infestation levels were not significantly different toward 6 of 7 parameters of the tree’s dimensions. The crown diameter, however, showed a significant difference toward all levels of infestation, except control (table 2). Results of ANOVA also showed that prevalence of mistletoe infestation found in the tree’s canopy having large quantities of mistletoes, with tree diameter range of 900–1,050 cm. That was because the crown diameter compared to the tree DBH presented a direct influence, which expanded for birds carrying the seed of the mistletoe. The larger the class of the crown diameter, the higher the infestation intensity of
mistletoes. Actually in the host teak, mistletoes only grew in the crown and nothing grew on stem part, therefore the size of the DBH did not present significant difference toward all levels of infestation. However, increased numbers of samples were needed to increase the accuracy of assessment on different levels of infestation in the OSP. Further effect of the crown diameter, also DBH and LCR toward infestation levels could be measured furthermore by conducting repeated measurements at the Permanent Sample Plot (PSP) every 6 or 12 months for ½ or 1 teak growth cycle.

Table 2. The Result of the test to determine the relationship between various infestation levels (TMR) to the tree dimensions.

| No | Tree dimension | Mistletoe infestation class at OSP |
|----|----------------|-----------------------------------|
|    |                | Not infected | Lightly infected | Moderately infected | Severely/very severely infected |
| 1  | DBH (cm)       |              |                  |                   |
|    | 32.99±(4.82)   | 35.30±(4.78) | 36.75±(5.09)     | 37.69±(3.34)      |
| 2  | LBD/BA (cm²/ha)| 922.29±(245.36) | 1014.93±(260.33) | 1090.64±(278.04)  |
|    | 0.79±(0.07)    | 0.81±(0.07)  | 0.79±(0.07)      | 0.82±(0.07)       |
| 3  | TT (m)         | 16.01±(3.06) | 17.20±(2.51)     | 18.12±(3.02)      | 19.23±(3.10)             |
| 4  | TBC (m)        | 3.14±(0.99)  | 3.23±(1.24)      | 3.69±(1.29)       | 4.06±(3.36)              |
| 5  | D crown (cm)   | 740.34±(214.85) | 889.71±(138.78) | 913.19±(206.67)  |
|    | 49.67±(5.17)   | 49.79±(5.05) | 49.59±(4.32)     | 51.62±(8.49)      |

*DBH (diameter breast height), LBD (basal area), LCR (leaf crown ratio) is the ratio of a live canopy to the total height of tree, TT (Total Height), TBC (free height branch), D (diameter crown); numbers followed by the same letter are not significantly different at α = 5% on the same row.

Significant differences of infestation levels caused by the Amyema miquelii (n = 95) to the Eucalyptus fasciculosa trees were observed at diameter (DBH) and the height parameters of the trees (n = 80). The diameter and the height of the infected trees were (13.6±0.6) cm and (6.8±0.2) m, respectively, while the diameter and the height of the non-infected trees were (10.3±0.5) cm and (5.6±0.2) m, respectively. [20].

No significant differences were observed on the tree height and the tree spacing to the infestation levels of the mistletoe at foureder research plots in the fragmented areas of the mountain forests of Central Veracruz, Mexico [21]. The volume growth parameter of the young western hemlock (Tsuga heterophylla) in British Columbia was lightly infested by the dwarf mistletoe and reduced by 15-25%. Severe infestation reduced the volume growth by 25-41% compared to the uninfected trees [22].

The LBD/BA trees’ parameter of the adult western hemlock’s (Tsuga heterophylla) in the Southeast area of Washington were used to measure the infestation levels of the dwarf mistletoe (Arceuthobium tsugense ssp. Tsugense) to the adult western hemlock’s [23]. The 13-year observation showed LBD/BA growth which was lightly infested (+1.4%), moderately infested (+ 3.8%), severely infested (-36%), compared to the non-infected trees [23].

A DMR -6 class test showed that infestation of the Arceuthobium vaginatum sub sp. Vaginatum on the 30-40 years-old Pinus hartwegii in the National Park Nevado de Colima Volcano, Mexico caused a decline in height growth (22%), in diameter (DBH) (9%), in volume (50%) compared to the non-infected trees [24]. A decrease by the same percentage has been observed in the current year of the increment (MC) and an annual average increment (MAI) of the residual trees of the infected Pinus hartwegii [24].

A distribution model of the Viscum album was studied on eight host species in Castle Lednice Park. The study observed that Acer campestre, Tilia cordata, T. platyphyllos infested host trees by growing inside the host’s canopy affecting the physiological and biomechanical aspects of the host trees, including the height, DBH, canopy projection area and volume header of the host trees [25].

Mistletoe infestation decreased the growth, caused defoliation and death to the fir (Abies cephalonica) in Greece based on an observation on 1,500 fir trees. However, there was no correlation between the infestation levels to the defoliation levels of fir leaves [26,27].
There was a tendency that mistletoe infested relatively large trees which had large crown diameters (table 2). This corresponded with other studies showing preferred infestation of the dwarf mistletoe *Arceuthobium douglasii* toward the douglas-fir having a larger size and a basal area [28].

The prevalence of *Dendrophthoe pentandra* infestation to the teak trees in Jahangirnagar University showed that 75% of the infestation occurred on older teak trees having larger size compared to younger teaks (11.11% infested) [10]. Spatial characteristics of the dwarf mistletoe infesting douglas-fir, one type of hemlock trees, showed that the tree diameter and height did not proportionally divide the infected and non-infected hemlock trees [29]. The mean diameter and height of the non-infested douglas-fir were 30.1 cm (22.9 m); lightly infested were 34.8 cm (25.1 m), severely infested were 37.0 cm (27.0 m).

Results that showed relationship among the diameter, LCR and the crown diameter categorized the host teak trees to the number of mistletoes per host teak (figure 2a, 2b, 2c). It was identified that the highest numbers of mistletoes per host tree have been observed at a diameter range of 50-55 cm i.e. (4.3±2.4). The highest numbers of mistletoes per host tree were observed at LCR range of 0.56-0.60 i.e. (6.7±4.7). As for the highest numbers of mistletoes per host tree were observed at a crown diameter range of 1,200 - 1,350 cm i.e. (4.1±1.2).

![Figure 2](image-url)

**Figure 2.** Distribution of the number of life mistletoes per host teak with a (a) diameter (n=176 host teak), (b) LCR (n=173 host teak) and (c) crown diameter (n=174 host teak) classes.
On figure 2, the number of host teak (n) was different for the DBH, LCR, and crown diameter class. This was because of the number of life the mistletoes had on that host teak which was actually different if grouped for those three dimension classes which was also different [2]. Besides, the Spearman correlation coefficients displayed a diameter class to the number of life mistletoes per host teak (n=175; r_s =0.0799), where the larger the diameter class, the more the number of mistletoes. However, the larger LCR class, the less the number of mistletoes (n=344; r_s = -0.2985), as for the larger the crown diameter class, the less the number of mistletoes (n=172; r_s = -0.1406). Nevertheless, those results were less accurate, so it is required for the addition of the sample number of those classes, to increase accuracy and validation of those results, which require additional numbers of those classes, respectively. Actually, to verify this result, other studies have observed that the mistletoe infestation did not occur to host trees, which had a crown diameter < 30 cm [30], which also indicated that the percentage of infested host trees increased with an increasing diameter of host trees’ canopy [30].

Results of this study also indicated that the numbers of mistletoes per host tree were affected by the dimension of the host trees i.e. diameter, LCR and crown diameter. Therefore, the number of mistletoe of host trees was included as the real variable in the assessment method for mistletoe infestation intensity on teak using modified the TMR-8 class rating (figure 1). Accuracy of this assessment method could be increased by adding the numbers of samples of host trees especially on several diameter classes, LCR, crown diameter that has not met the teak samples of the host and the mistletoe in this study.

3.1.2. Sub rating: the intensity of infected branches (icd).

Inside the 0.25 ha OMP, the average dieback of host trees due to light infestation was 7.5 ± 1.3, while the average of the moderate infestation was 11.3 ± 1.0 and the average of the severe infestation was 13.8 ± 2.1 (table 3). The amount of host trees having dieback (30.0% - 46.5%) was lower than a total combination of non-infested teak trees and infested teak host trees without dieback (53.5% - 54.0%). Generally, teak host trees (29.9% - 52.6%) suffered dieback with a severity scale of 0 - 40% (table 3).

### Table 3. Intensity of infected branch (icd) (%) and dieback (%) on host teak trees at Padangan CSO.

| OMP | Numbers of teak host trees with icd (%) | Numbers of teak host trees with dieback (%) (severity scale) |
|-----|----------------------------------------|----------------------------------------------------------|
|     | 0-50 | ≤50 | 0-10 | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 | 80-90 |     |
| Light | 25 | 0 | 18 | 2 | 3 | 0 | 2 | 0 | 0 | 0 |
|     | 25 | 0 | 16 | 1 | 6 | 1 | 0 | 1 | 0 | 0 |
|     | 23 | 0 | 16 | 4 | 1 | 2 | 0 | 0 | 0 | 0 |
|     | 24 | 0 | 18 | 4 | 2 | 0 | 0 | 0 | 0 | 0 |
| Total | 97 | 0 | 67 | 11 | 13 | 3 | 2 | 1 | 0 | 0 |
| Average | 24.3±1.0 | 0 | 17.0±1.2 | 7.3±1.3 |
| Moderate | 21 | 1 | 11 | 4 | 6 | 0 | 0 | 0 | 0 | 1 |
|     | 24 | 0 | 12 | 7 | 2 | 2 | 1 | 0 | 0 | 0 |
|     | 22 | 4 | 14 | 4 | 2 | 2 | 4 | 0 | 0 | 0 |
|     | 24 | 1 | 15 | 2 | 4 | 4 | 0 | 0 | 0 | 0 |
| Total | 91 | 6 | 45 | 19 | 17 | 8 | 7 | 0 | 0 | 1 |
| Average | 22.8±1.5 | 1.5±1.7 | 13.0±1.8 | 11.3±1.0 |
| Severe | 25 | 6 | 16 | 1 | 6 | 3 | 3 | 1 | 1 | 0 |
|     | 25 | 1 | 15 | 4 | 5 | 2 | 0 | 0 | 0 | 0 |
|     | 23 | 2 | 13 | 4 | 3 | 4 | 1 | 0 | 0 | 0 |
|     | 18 | 6 | 13 | 2 | 5 | 1 | 3 | 0 | 0 | 0 |
| Total | 91 | 15 | 51 | 12 | 21 | 10 | 9 | 2 | 1 | 0 |
| Average | 22.8±3.3 | 3.8±2.6 | 14.3±1.5 | 12.3±1.9 |

The results displayed in table 4 showed the relationship between the intensity of infected branches (icd) and dieback to the infestation levels (light, moderate, severe). Infected branches were gradually deteriorated into dieback. The ≥ 50% icd was significantly different at light and moderate infestations,
and at moderate and severe infestations (table 4). Infestation on branches without dieback was significantly different suffering light and moderate infestations and at light and severe infestations. Dieback occurrences had highly significant differences at light and moderate infestations and at light and severe infestations. Therefore, infected branches (icd) were important variables to be used as sub-rating on the assessment method for mistletoe infestation intensity (figure 1). The dieback was used to describe the infestation condition (table 1).

### Table 4. Results of ANOVA on intensity of infested branches (icd) and dieback (mp) among different levels of infestation.

| % icd and % mp | n * | ANOVA | DMRT (p < 0.05) |
|----------------|-----|-------|-----------------|
| icd 0-50%      | 279 | 0.480 | > 0.05          |
| icd ≥ 50%      | 21  | 0.048 | < 0.05<sup>b</sup> light vs. moderate; light vs. severe moderate vs. severe |
| mp 0%          | 163 | 0.013 | < 0.05          light vs. moderate; light vs. severe |
| mp 0-10%       | 42  | 0.396 | > 0.05          |
| mp 10-20%      | 51  | 0.411 | > 0.05          |
| mp 20-30%      | 21  | 0.211 | > 0.05          |
| mp 30-40%      | 18  | 0.524 | > 0.05          |
| mp 40-50%      | 3   | 0.622 | > 0.05          |
| mp 50-60%      | 1   | 0.405 | > 0.05          |
| mp 60-70%      | -   | -     | -               |
| mp 70-80%      | -   | -     | -               |
| mp 80-90%      | 1   | 0.405 | > 0.05          |
| mp 90-100%     | -   | -     | -               |
| mp 0-100%      | 137 | 0.002 | < 0.01<sup>c</sup> light vs. Moderate; light vs. severe |

<sup>a</sup>the sum of samples  
<sup>b</sup>the difference is significant at α = 5%  
<sup>c</sup>the difference is highly significant at α = 1%

### 3.1.3. Simplifying the assessment method for mistletoe infestation intensity.

Based on the TMR-8 class rating, the intensity of mistletoe infestation at Padangan CSO ranged from 0.86 to 3.78 (light to moderate) and has not reached the severe level (TMR > 5). In Padangan CSO, the ≥ 50% prevalence was reached at moderate and severe levels of infestation [2].

Cross-tabulation between the infestation intensity and prevalence showed that the accuracy of classification was 58.33%. Therefore, the estimated TMR value tended to underestimate the prevalence value. It was suggested to expand the size of OMP unit on infestation having high prevalence (≥ 85%) [2]. The modified TMR-8 class rating method still needed further implementation in other Clonal Seed Orchard and Forest Management Unit locations for verification and validation. It was also suggested to use both the TMR and the prevalence value in the current assessment method for mistletoe infestation intensity. As investigated, the numbers of mistletoe per host tree and infestation intensity were two significant variables to determine TMR value. Therefore, the use of TMR-8 class rating in this study was acceptable and feasible.

In the field, the practical and simple way to determine the value of modified TMR could be conducted by only counting the numbers of mistletoes per host tree, without considering the intensity of infected branches. It was much easier to count the numbers of mistletoes per host tree, rather than counting the numbers of infected branches. The standardized range for modified TMR-8 class and simplified TMR is displayed in table 5 [2].
Table 5. The simplified TMR-8 class rating method (which undertaken in this study).

| Infestation criteria | TMR-8 class (Rating scale) | TMR 8-class (Sub-rating scale) | Simplified TMR-8 class rating (numbers of mistletoes per host tree) |
|----------------------|----------------------------|--------------------------------|---------------------------------------------------------------|
| No infestation       | No infestation             | 0                              | 0                                                             |
| Light                | Rather light               | 0.1 – 2.0                      | 1                                                             |
| Light                | Light                      | 2.1 – 3.0                      | 2                                                             |
| Moderate             | Rather moderate            | 3.1 – 4.0                      | 3                                                             |
| Moderate             | Moderate                   | 4.1 – 5.0                      | 4                                                             |
| Severe               | Rather severe              | 5.1 – 6.0                      | 5                                                             |
| Severe               | Severe                     | 6.1 – 7.0                      | 6                                                             |
| Very severe          | Very severe                | ≥7.0                           | ≥7a                                                           |

*In accordance with the criteria of severe infestation [5]*

4. Conclusions
Number of life mistletoes per host teak tended to increase to the larger tree diameter. The crown diameter presented significantly different levels of mistletoe infestation. As investigated, the ≥ 50% intensity of infected branches was significantly in different levels of infestation (light, moderate, severe). These results validated the use of numbers of mistletoes and the intensity of infected branches parameters in the assessment method for mistletoe infestation intensity using the modified TMR-8 class rating in this study.

5. Recommendations
It is necessary to conduct verification and validation tests of this assessment method by implementing the modified TMR-8 class rating in other Clonal Seed Orchards and other Forest Management Units using numbers of mistletoes and intensity of infected branches as significant parameters.

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References

[1] Sumantoro P 2005 Hama dan penyakit tanaman jati. [dalam Seperempat abad pemuliaan jati Perum Perhutani ed Sadhardjo S et al.] (Cepu: Pusat Pengembangan Sumber Daya Hutan Perum Perhutani)

[2] Muttakin Z. 2016 Karakter biologi benalu pada jati di Kebun Benih Klonal (KBK) Padangan, Perum Perhutani [Disertation] (Bogor: Bogor Agricultural Univerisity)

[3] Rahmadwati R, Sadono R, Supriyatno N 2016 Preliminary stand table for average dominant of Jati Plus Perhutani in Saradan, Madian, and Ngawi Districts JMHT 22(1) 57–64

[4] Corryanti 2015 Karakter pohon jati (Tectona grandis Linn F.) di Kebun Benih Klonal (Cepu: Puslitbang Perhutani)

[5] Center of Research and Development Perhutani 2013 Of data sum of tree that infected mistletoe in CSO Padangan (Inventory result in October 2013) (Cepu: Center of Research and Development Perhutani)

[6] Corryanti and Wahyudi T 2015 Mengenal sumber benih jati: Kebun Benih Klonal (Clonal Seed Orchard) (Cepu: Puslitbang Perhutani)

[7] Azpeitia F and Lara C 2006 Reproductive biology and pollination of the parasitic plant Psittacanthus calyculatus (Loranthaceae) in central Mexico J.Torrey Bot. Soc. 133(3) 429–438

[8] Howell B End Robert L M 2004 Growth impacts of Psittacanthus angustifolius Kuijt on Pinus oocarpa Schiede in Honduras For. Ecol. Manage. 198 75–88

[9] Lezama R P and Melgar J C 1999 Estudio del muérdago en coniferas de la zona central de
Honduras Tatascan 11 65–73 (in Spanish)

[10] Sikder Md M and Khair A 2011 Prevalence of plant parasitic infestation to plantation trees at Jahangirnagar University Campus Bangladesh J. Life Sci 23(2) 25–31

[11] Hafiziansyah G 1998 Evaluasi kesesuaian tanaman mangium dan gmelina di areal HPHTI PT Surya Hutani Jaya Provinsi Kalimantan Timur [Thesis] (Bogor: Bogor Agricultural University)

[12] Muttaqin Z 2002 Evaluasi kualitas tapak tegakan mangium dan gmelina di areal HPHTI PT Surya Hutani Jaya Provinsi Kalimantan Timur [Thesis] (Samarinda: Universitas Mulawarman)

[13] Drescher J, Rembold K, Allen K, Beckschäfer P, Buchori D, Clough Y, Faust H, Fauzi AM, Gunawan D, Hertel D, Irawan B, Kleinn C, Knohl A, Kotowska M M, Krashevska V, Krishna V, Leuschner C, Lorenz W, Meijide A, Melati D, Nomura M, Pérez-Cruzado C, Qaim M, Siregar I Z, Steinebach S, Tscharntke T, Wick B, Wiegand K, Kreft H and Scheu S 2016 Ecological and socio-economic functions across tropical land use systems after rainforest conversion Phil. Trans. R. Soc. B. 371 20150275

[14] Muttaqin Z, Budi S W, Basuki W, Iskandar Z S, Corryanti 2016 Assessing intensity of mistletoe infestation in teak clonal seed orchard (CSO) Padangan, East Java Procedia Environ. Sci. 33 404–415

[15] Dunn PH 1999 Forest Health Monitoring: Field Methods Guide (National1999) (Washington: National Forest Health Monitoring Program-Research Triangle Park)

[16] Rist L, Uma S, Milner-Gulland and Jaboury G 2008 Managing mistletoe: The value of local practices for a non-timber forest resource For. Ecol. Manage 255 1684–1691

[17] Herdiana N 2010 Potensi serangan hama tanaman jati rakyat dan upaya pengendaliannya di Rumpin, Bogor Jurnal Penelitian Hutan 7(4) 177–185

[18] Salvador M M, Huendo S M, Collazo I V, Bautista E V, Nieto C R and Guerrero F V 2014 Effect of Arceuthobium vaginatum (Willd.) Presl. subsp. Vaginatum in Pinus hartwegii Lindl. In Colima State Revista Mexicana de Ciencias Forestales 6(29) 44–45

[19] Baltazár T, Pejchal M and Varga I 2015 Modelling of the distribution of European mistletoe (Viscum album) with dependence on local factors in the Castle Park in Lednice Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 63(5) 1441–52

[20] Rafroyannis Y, Radoglou K and Bredemeier M 2015 Effects of mistletoe infestation on the decline and mortality of Abies cephalonica in Greece Ann. For. Res. 58(1) 55–65

[21] Olivia J and Colinas C 2007 Decline of silvir fir (Abies alba Mill.) stands in the Spanish Pyrenees: Role of management, historic dynamics and pathogens For. Ecol. Manage. 252 84–97

[22] Geils B W and Mathiasen R L 1990 Intensification of dwarf mistletoe on Southwestern Douglas-fir. Forest Science 36(4) 955–969
[29] Shaw D C, Chen J, Freeman E A and Braun D M 2005 Spatial and population characteristics of dwarf mistletoe infected trees in an old-growth Douglas-fir-western hemlock forest Can. J. For. Res. 35 990–1001

[30] Mourão F A, Jacobi C M, Figuera J E C and Batista E K L 2009 Effects of the parasitism of Struthanthus flexicaulis (Mart.) Mart. (Loranthaceae) on the fitness of Mimosa calodendron Mart. (Fabaceae), an endemic shrub from rupestrian fields over ironstone outcrops, Minas Gerais State, Brazil Acta bot. bras. 23(3) 820–5