Effect of breeding technology and trunk axial position on shrinkage and quality of 10 year old teak wood as a furniture’s raw material

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Abstract. Shortage on teak wood availability as material for furniture industry has been solved by developing tree breeding technology and decreasing on cut rotations. Three types of teak forest breeding technology being developed is called APB, KBK and JPP-PHT-1. Breeding technology was developed as an effort to get productive and high quality of teak stands. Decreasing on cutting rotation encourages to increase young wood utilization. This study was aimed to determine the effect of breeding technology and axial stem position on teak wood shrinkages and wood quality of 10 years old. Nine trunk of 10 years old teak trees were harvested on forest areas of Nganjuk Forest District, East Java Province. These trees consisted of seedling grown by APB, KBK and JPP-PHT-1 breeding technology of which consisted of three trees on each kind of breeding technology. Three disks were taken from each trunk, namely from the butt, middle and upper parts. Wood shrinkages on tangential and radial and its ratio were measured based on British Standard method. Data were analyzed by using variance analysis arranged in blocked factorial and further testing were performed by using HSD Duncan. Wood quality was determined by using Suranto method. Results showed that interaction of two factors did not affect on tangential and radial shrinkages and also tangential-radial ratio. Tree breeding technology very significantly affects on tangential shrinkage and significantly effect on radial shrinkage. APB breeding technology produces the greatest tangential shrinkage (8.46), followed by KBK (6.62) and JPP-PHT-1 (6.59%). APB breeding technology produces the greatest radial shrinkage (5.51), followed by KBK (5.08) and JPP-PHT-1 (4.42%). The axial tree trunk position affects only on tangential and radial ratio. The stem base has a largest T/R ratio (1.84), followed by middle part (1.45) and upper part (1.26). In term of wood shrinkage, Breeding technology affects the wood quality. APB breeding technology produces the lowest timber quality (3.30), followed by JPP-PHT-1 (2.85), and KBK (2.78).

1. Introduction
Teak furniture industry faces many obstacles, among others are the limited availability of high quality wood [1]. This problem is solved by the use of young timber as a whole, either from the base, the middle or the end of the tree trunk. In addition, forestry companies of Perhutani has developed superior teak seedlings with rapid tree growth rates. The three types of seeds include seeds of APB (seeds from Seed Production Areas), seeds of KBK (seeds from the Clonal Seed Orchard) and seedlings of JPP PHT-1 (shoots from clonal seed orchard) [2]. These seeds have been planted together in the forest and there are
10 years old plantation. The tree growth rate has most likely affected the nature and quality of wood [3]. Therefore, the nature and quality of the wood produced from tree trunks derived from the seeds need to be studied [4].

The quality of the wood is a reflection of the level of compatibility between the properties of wood with the demands of the requirements needed for a particular use. The more suitable the properties of wood to the demands of specific requirements for the use of wood, the higher the wood quality [5]. The properties of wood covering the basic properties and the properties of wood processing. The wood basic properties are anatomical properties and physical properties of wood [6,7]. Three parameters measuring the wood physical properties are tangential shrinkage, radial shrinkage and radial-tangential shrinkage ratio.

The aims of these research were to achieve two things. First, to determine the effect of breeding technology for seed trees production and trunk axial position and their interaction to the wood shrinkage properties. Second, determine the quality of teak wood as a furniture material based on the parameters of wood shrinkages.

2. Material and Methods

2.1. Materials

Research materials were 9 trunk of 10 years old teak trees harvested from research plots compartment located on forest areas of Nganjuk Forest District, East Java Province. These trees consisted of seedling grown by APB, KBK and JPP-PHT-1 breeding technology which consisted of three trees on each kind of breeding technology.

2.2. Methods

The study was conducted by the following procedure, i.e. (1) cutting down nine sample trees. (2) separate the branch-free trunk into tree parts, namely butt, middle and upper part of the stem. (3) Take a disk in a thickness of 3 cm on every part of the trunk. (4) testing on tangential shrinkage and radial shrinkage based on British Standard 1957 method and calculating tangential-radial shrinkage ratio, (5) classifying wood quality of APB, KBK and JPP PHT-1 by using the standard of classification proposed by Suranto [8].

2.3. Data analysis

The research involved two factors, namely the breeding technology and axial position of branch-free trunk. Factor of breeding technology in producing seed consist of three levels, namely APB, KBK and JPP PHT-1. The later breeding technology the newer one. Factor of axially wood position consisted of three levels, namely the butt, middle and upper of the trunk. Each treatment combination was replicated three times, so the research was obtained 27 units sample.

Results of research was analyzed by using variance analysis which arranged in completely randomized factorial design [9]. Further testing was done by using Honestly Significant Different (HSD). Classification method arranged by Suranto [8] was used to classify and to rank wood quality. Wood quality were classified into five classes, namely class 1 (very good), class 2 (good), class 3 (sufficient/moderate), class 4 (bad) and class 5 (very bad).

3. Results and Discussion

3.1. Results

Research was carried out on three parameters, namely tangential shrinkage, radial shrinkage and the ratio of both shrinkages. The results are presented sequentially in Table 1, Table 2 and Table 3.
Table 1. Results of tangential shrinkage measurement (%)

| Breeding technology method | Axial position | Replication 1 | Replication 2 | Replication 3 | Average |
|---------------------------|----------------|---------------|---------------|---------------|---------|
| APB                       | Butt           | 10.70         | 8.87          | 7.24          | 8.94    |
|                           | Middle         | 8.77          | 8.65          | 8.37          | 8.54    |
|                           | Top            | 9.84          | 6.75          | 6.97          | 7.84    |
|                           | Butt           | 8.03          | 7.99          | 6.71          | 7.58    |
| KBK                       | Middle         | 7.13          | 5.82          | 6.29          | 6.41    |
|                           | Top            | 5.23          | 5.20          | 7.20          | 5.88    |
|                           | Butt           | 5.59          | 6.47          | 8.02          | 6.69    |
| JPP PHT-1                 | Middle         | 5.45          | 6.21          | 7.22          | 6.29    |
|                           | Top            | 6.99          | 6.39          | 6.95          | 6.78    |

Table 2. Results of radial shrinkage measurement (%)

| Breeding technology method | Axial position | Replication 1 | Replication 2 | Replication 3 | Average |
|---------------------------|----------------|---------------|---------------|---------------|---------|
| APB                       | Butt           | 10.70         | 8.87          | 7.24          | 8.94    |
|                           | Middle         | 8.77          | 8.65          | 8.37          | 8.54    |
|                           | Top            | 9.84          | 6.75          | 6.97          | 7.84    |
|                           | Butt           | 8.03          | 7.99          | 6.71          | 7.58    |
| KBK                       | Middle         | 7.13          | 5.82          | 6.29          | 6.41    |
|                           | Top            | 5.23          | 5.20          | 7.20          | 5.88    |
|                           | Butt           | 5.59          | 6.47          | 8.02          | 6.69    |
| JPP PHT-1                 | Middle         | 5.45          | 6.21          | 7.22          | 6.29    |
|                           | Top            | 6.99          | 6.39          | 6.95          | 6.78    |

Table 3. Results of tangential-radial ratio

| Breeding technology method | Position | Replication 1 | Replication 2 | Replication 3 | Average |
|---------------------------|----------|---------------|---------------|---------------|---------|
| APB                       | Butt     | 1.84          | 1.31          | 1.49          | 1.55    |
|                           | Middle   | 1.59          | 2.31          | 1.53          | 1.81    |
|                           | Top      | 1.54          | 1.22          | 1.26          | 1.34    |
|                           | Butt     | 3.84          | 2.08          | 1.68          | 2.54    |
| KBK                       | Middle   | 1.28          | 2.26          | 1.15          | 1.23    |
|                           | Top      | 1.09          | 1.09          | 1.55          | 1.24    |
|                           | Butt     | 1.55          | 1.27          | 1.46          | 1.43    |
| JPP PHT-1                 | Middle   | 1.17          | 1.35          | 1.41          | 1.31    |
|                           | Top      | 1.35          | 1.05          | 1.18          | 1.19    |
3.2. Results analysis

3.2.1. Analysis of variance

Analysis of variance was elaborated to determine the effect of breeding technology and trunk axial position as well as interaction of these two factors to three parameters. Analysis result on Tangential shrinkage, radial shrinkage and tangential-radial shrinkage ratio are presented consecutively in Table 4, 5 and 6.

Table 4. Analysis of variance on tangential shrinkage (%)

| Source      | Sum of Squares | DF | Mean Square | F     | Significance |
|-------------|----------------|----|-------------|-------|--------------|
| Corrected Model | 27.475*         | 8  | 3.434       | 2.877 | 0.030        |
| Intercept   | 1409.056       | 1  | 1409.056    | 1180.443 | 0.000       |
| Method (M)  | 20.701         | 2  | 10.350      | 8.671** | 0.002       |
| Position (P)| 3.849          | 2  | 1.925       | 1.612  | 0.227        |
| M * P       | 2.925          | 4  | 0.731       | 0.613  | 0.659        |
| Error       | 21.486         | 18 | 1.194       |        |              |
| Total       | 1458.016       | 27 |             |        |              |
| Corrected Total | 48.961         | 26 |             |        |              |

Table 5. Analysis of variance on radial shrinkage (%)

| Source      | Sum of Squares | DF | Mean Square | F     | Significance |
|-------------|----------------|----|-------------|-------|--------------|
| Corrected Model | 14.913*        | 8  | 1.864       | 3.438 | 0.014        |
| Intercept   | 675.800        | 1  | 675.800     | 1246.259 | 0.000       |
| Method (M)  | 5.455          | 2  | 2.727       | 5.030* | 0.018       |
| Position (P)| 2.972          | 2  | 1.486       | 2.741  | 0.091        |
| M * P       | 6.486          | 4  | 1.622       | 2.990  | 0.057        |
| Error       | 9.761          | 18 | 0.542       |        |              |
| Total       | 700.474        | 27 |             |        |              |
| Corrected Total | 24.674         | 26 |             |        |              |

Table 6. Analysis of variance on tangential-radial shrinkage ratio

| Source      | Sum of Squares | DF | Mean Square | F     | Significance |
|-------------|----------------|----|-------------|-------|--------------|
| Corrected Model | 4.392*         | 8  | 0.549       | 2.830 | 0.032        |
| Intercept   | 61.956         | 1  | 61.956      | 319.348 | 0.000       |
| Method (M)  | 0.614          | 2  | 0.307       | 1.583  | 0.233        |
| Position (P)| 1.553          | 2  | 0.777       | 4.003* | 0.036        |
| M * P       | 2.224          | 4  | 0.556       | 2.866  | 0.053        |
| Error       | 3.492          | 18 | 0.194       |        |              |
| Total       | 69.840         | 27 |             |        |              |
| Corrected Total | 7.884          | 26 |             |        |              |
Based on the analysis of variance in Table 4, it can be seen that breeding technology method influences very significantly to the mean value of tangential shrinkage, while the stem axial position and their interaction has no significant effect. Meanwhile, the analysis of variance in Table 5 shows that breeding technology method has a very significant effect on the mean of radial shrinkage value, while the axial position of the stem and their interaction have no significant effect. On the other hand, the analysis of variance in Table 6 shows that the stem axial position has a very significant effect on the mean value of the tangential-radial shrinkage ratio, while the breeding technology method and their interaction has no significant effect. Thus, further testing by using HSD Duncan method needs to be done on the factors that expressed a significantly affect.

3.2.2. HSD Duncan analysis

Duncan's HSD analysis was conducted to determine the difference in the level of breeding technology method to tangential shrinkage. The results are presented in Table 7 below.

| Breeding Technology Method | N  | Subset |
|----------------------------|----|--------|
| JPP PHT-1                  | 9  | 6.59   |
| KBK                        | 9  | 6.62   |
| APB                        | 9  | 8.46   |

Based on the test results shows in Table 7 above, it is seen that tangential shrinkage on APB (8.46%) differs significantly to KBK (6.62%) and JPP PHT-1 (6.59%), but KBK and JPP IPM-1 breeding technology has no different value on tangential shrinkage.

Duncan's HSD analysis was conducted to determine the difference in the level of breeding technology method to radial shrinkage. The results were presented in Table 8 below.

| Breeding Technology Method | N  | Subset |
|----------------------------|----|--------|
| KBK                        | 9  | 4.42   |
| JPP PHT-1                  | 9  | 5.08   |
| APB                        | 9  | 5.51   |

The test in Table 8 above shows that radial shrinkage on JPP PHT-1 (5.08%) did not differ to KBK (4.42%) and APB (5.51%). Meanwhile, radial shrinkage on KBK is significantly different APB breeding technology.

Duncan's HSD analysis was performed to determine the difference in the level of stem axial position on tangential - radial shrinkage ratio. The results are presented in Table 9 below.
Based on the results of the test presented in Table 9, it is seen that the value of tangential/radial shrinkage ratio at the middle position of the stem (1.45) does not differ significantly to the both of stem butt position (1.84) and stem top position (1.26), but these latter two positions have a significant different on tangential / radial shrinkage ratios.

3.3. Discussion

3.3.1. Tangential shrinkage

The analysis of variance in Table 4 shows that the breeding technology method has a very significant effect, while stem axial position and the interaction between the two factors have no significant effect on tangential shrinkage. Thus, the total of tangential shrinkage of stem butt position (7.74%) and the middle stem position (7.10%) and the top of the stem (6.84%) were not different.

Based on the HSD Duncan test results presented in Table 7, it was seen that the tangential shrinkage in APB (8.46%) differs significantly to KBK (6.62%) and JPP PHT-1 (6.59%), but total tangential shrinkage on KBK and JPP PHT-1 were not different. Thus, the total tangential shrinkage of the wood grown from the both sources of clonal seed orchard did not difference. Thus, the generative (KBK) and vegetative planting material (JPP PHT-1) taken from clonal seed orchard have the same values in term of tangential shrinkage. Meanwhile, the total tangential shrinkage on wood grown from the clonal seed orchard was smaller than the wood grown from the seed garden area (APB).

The smaller tangential shrinkage in the APB (8.46%) compared to KBK (6.62%) and the JPP PHT-1 (6.59%) breeding technology may be due to the specific gravity factor. The value of specific gravity of wood grown by these three seeding methods also decreases respectively. Specific gravity of wood grown by APB was 0.50, KBK was 0.46 and JPP PHT-1 was 0.46 [10]. The linkage between specific gravity and tangential shrinkage was in line to the theoretical basis that the specific gravity affects tangential shrinkage [7].

3.3.2. Radial shrinkage

The analysis of variance on Table 5 shows that breeding technology method significantly influences radial shrinkage, while the stem axial position and their interaction of the two factors were not significantly influenced. Thus, the radial shrinkage at stem butt (4.61%), the stem middle (4.97%) and the stem top position (5.42%) were not significantly different.

Testing result presented in Table 8 shows that wood radial shrinkage on JPP PHT-1 (5.08%) was not differ to KBK (4.42%) and APB (5.51%). Meanwhile, total radial shrinkage on KBK was different to APB. The total radial shrinkage of the wood grown from the clonal seed orchard, whether taken in vegetative form (JPP PHT-1) or generative form (KBK), has a lower value than that taken in generative form from seed production area (APB).

When the results of this research compared to the results of similar research conducted by Matumura and Kawasaki [11], both of the values were the nearly same. The results of Matumura and Kawasaki [11] research on young 16 years old teak growing in Gunungkidul Yogyakarta get radial shrinkage value of 3.06+0.49 and 51 years old teak growing in KPH Pemalang get radial shrinkage value of 2.75+0.44, while the results of this study get an average value of 3.27%.

### Table 9. HSD Duncan test result for influence of stem axial position on ratio of tangential - radial shrinkage

| Stem axial position | N  | Subset 1 | Subset 2 |
|---------------------|----|----------|----------|
| Top                 | 9  | 1.26     |          |
| Middle              | 9  | 1.45     | 1.45     |
| Butt                | 9  |          | 1.84     |
| Significance        | 0.37| 0.08     |          |
3.3.3. Tangential-radial shrinkage ratio

The analysis of variance presented in Table 6 shows that the stem axial position has a very significant effect on the tangential/radial shrinkage ratio. Meanwhile, the factor of breeding technology method and its interaction to stem axial position has no significant effect. Thus, the ratio of tangential/radial shrinkage on wood grown by APB seedlings (1.57), KBK (1.67) and PHT-1 (1.31) were not significantly different.

The testing result presented in Table 9 shows that the value of tangential/radial shrinkage ratio at the stem middle position (1.45) is not significantly different both to the stem butt position (1.84) or to the stem top position (1.26). But the last two positions have different shrinkage ratios. The mean tangential/radial shrinkage ratio resulted in this study was 1.52.

If the results of this study were compared to the research results conducted by Matumura and Kawasaki [11], which were get the value of this ratio of 2.4 for 16 years old teak wood that grows in Gunungkidul Daerah Istimewa Yogyakarta and of 1.95 for 51 years old teak wood that grew in compartment of 46A, RPH Klapanunggal, BKPH Bantarsari, KPH Pemalang, it was seen that the results of this study get a relatively low value of this shrinkage ratio.

3.4. Discriminant analysis of wood quality

Discriminant analysis was conducted with the aim to know the effect of breeding technology method, and stem axial position and the interaction of these two factors to the wood quality class. Classification was determined by using parameters of tangential depreciation, radial shrinkage and tangential/radial arrangement ratio. The standard of wood quality determination was done based on Suranto method [8]. This classification standard is presented in Table 10.

| Wood quality class | Tangential shrinkage | Radial shrinkage | T/R shrinkage ratio |
|--------------------|----------------------|------------------|---------------------|
| 1                  | < 4.81               | < 0.83           | < 0.98              |
| 2                  | 4.81-6.77            | 0.83-2.46        | 0.98-2.13           |
| 3                  | 6.77-8.72            | 2.46-4.09        | 2.13-3.28           |
| 4                  | 8.72-10.68           | 4.09-5.72        | 3.28-4.44           |
| 5                  | >10.68               | > 5.72           | > 4.44              |

Based on the classification standard, the process of wood quality rating was done partially on the perspective of those three parameters. The result was then calculated to obtain average value. This average value describes the quality of wood from the shrinkage point of view. Resulted wood quality rating class were presented in Table 11, while the recapitulation was presented in Table 12.

Based on Table 12 presented above, it can be seen that the quality class of teak produced by APB was 3.30 and KBK was 2.78 and JPP PHT-1 seedling technology was 2.85. Meanwhile, the quality class of 10 years old teak wood taken from the stem butt position was 3.07 and the stem middle position was 3.85 and the top position of the stem was 3.
### Table 11. Wood quality classification based on shrinkage parameter

| Sample codification | Axial position | Total shrinkage (%) | Wood quality class on parameter of | Average quality class |
|---------------------|----------------|---------------------|-----------------------------------|-----------------------|
|                     |                | T       | R       | T/R     | T       | R       | T/R     |          |
| APB 1               | Butt           | 10.70  | 5.82   | 1.84   | 5       | 5       | 2       | 4.00     |
|                     | Middle         | 8.77   | 5.51   | 1.59   | 4       | 4       | 2       | 3.33     |
|                     | Top            | 9.84   | 6.41   | 1.54   | 4       | 5       | 2       | 3.67     |
| APB 2               | Butt           | 8.87   | 6.76   | 1.31   | 4       | 5       | 2       | 3.67     |
|                     | Middle         | 8.65   | 3.75   | 2.31   | 3       | 3       | 2       | 2.67     |
|                     | Top            | 6.75   | 5.51   | 1.22   | 2       | 4       | 2       | 2.67     |
| APB 3               | Butt           | 7.24   | 4.85   | 1.49   | 3       | 4       | 2       | 3.67     |
|                     | Middle         | 8.37   | 5.46   | 1.53   | 3       | 4       | 2       | 3.00     |
|                     | Top            | 6.97   | 5.54   | 1.26   | 3       | 4       | 2       | 3.00     |
| KBK 1               | Butt           | 8.03   | 2.09   | 3.84   | 3       | 3       | 4       | 3.33     |
|                     | Middle         | 7.13   | 5.57   | 1.28   | 3       | 4       | 2       | 3.00     |
|                     | Top            | 5.23   | 4.79   | 1.09   | 2       | 4       | 2       | 2.67     |
| KBK 2               | Butt           | 7.99   | 3.83   | 2.08   | 3       | 3       | 2       | 2.67     |
|                     | Middle         | 5.82   | 4.62   | 1.26   | 2       | 4       | 2       | 2.67     |
|                     | Top            | 5.20   | 4.77   | 1.09   | 2       | 4       | 2       | 2.67     |
| KBK 3               | Butt           | 6.71   | 3.98   | 1.68   | 2       | 3       | 2       | 2.33     |
|                     | Middle         | 6.29   | 5.47   | 1.15   | 2       | 4       | 2       | 2.67     |
|                     | Top            | 7.20   | 4.65   | 1.55   | 3       | 4       | 2       | 3.00     |
| JPP PHT 1           | Butt           | 5.59   | 3.60   | 1.55   | 2       | 3       | 2       | 2.33     |
|                     | Middle         | 5.45   | 4.64   | 1.17   | 2       | 4       | 2       | 2.67     |
|                     | Top            | 6.99   | 5.16   | 1.35   | 3       | 4       | 2       | 3.00     |
| JPP PHT 2           | Butt           | 6.47   | 5.08   | 1.27   | 2       | 4       | 2       | 2.67     |
|                     | Middle         | 6.21   | 4.61   | 1.35   | 2       | 4       | 2       | 2.67     |
|                     | Top            | 6.39   | 6.09   | 1.05   | 2       | 5       | 2       | 3.00     |
| JPP PHT 3           | Butt           | 8.02   | 5.50   | 1.46   | 3       | 4       | 2       | 3.00     |
|                     | Middle         | 7.22   | 5.13   | 1.41   | 3       | 4       | 2       | 3.00     |
|                     | Top            | 6.95   | 5.89   | 1.18   | 3       | 5       | 2       | 3.33     |

### Table 12. Recapitulation of wood quality class

| Breeding technology | Wood quality class on stem position | Average wood quality class |
|--------------------|-------------------------------------|----------------------------|
|                    | Butt                               | Middle                    | Top                        |
| APB                | 3.78                               | 3.00                      | 3.11                      | 3.30                      |
| KBK                | 2.78                               | 2.78                      | 2.78                      | 2.78                      |
| JPP-PHT 1          | 2.67                               | 2.78                      | 3.11                      | 2.85                      |
| Average            | 3.07                               | 3.85                      | 3.00                      | 3.30                      |
4. Conclusion

Three points of conclusion was presented as follows:

a. The interaction of two factors, namely the breeding technology and stem axial position affect to radial shrinkage, but was not affect the tangential shrinkage and tangential/radial shrinkage ratio

b. Breeding technology method affects very significantly to tangential shrinkage and radial shrinkage. Seeds prepared by JPP PHT-1 resulted the smallest tangential shrinkage (6.59%), followed by KBK (6.62%) and APB (8.46%). Wood grown by KBK seeds resulted the smallest radial shrinkage (4.42%), followed by JPP PHT-1 (5.08%) and APB (5.51%). (b) The stem axial position affected the tangential / radial shrinkage ratio. The stem butt position has the largest ratio (1.84), followed by the middle (1.45) and the top of the stem (1.26)

c. Breeding technology method resulted the highest wood class owned by KBK (2.78) followed by JPP PHT-1 (2.85) and APB (3.30). (b) Stem axial position produced a highest wood quality class owned by stem butt position (2.67), followed by the middle part (2.78) and top part of the stem (3.11).

One point to be recommended as follows, breeding technology of JPP PHT-1 method needs to be socialized as it produces the wood which classified on quality class of 2.85 at the age of 10 years and the highest wood volume compared to KBK and APB methods.

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