ACIAR Project FST/2012/092

Enhancing Value Added Wood Processing in Papua New Guinea

Enhancing the knowledge of wood properties and processing characteristics of PNG timbers

Machining characteristics of PNG timber species

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Context

The aim of the ACIAR project FST/2012/092 is to increase the contribution that utilisation of forest resources makes to national and local economies, including landowners and processors, through the development of domestic value-added wood processing methods. The specific objective of activity 1.6 is to assess the processing characteristics required to successfully produce value-added products for Papua New Guinea and export markets. Therefore, a machining testing program has been developed including the planing behaviour of selected PNG wood species under cutting tools. The testing program has been conducted at the Timber and Forestry Training College (TFTC) according to relevant international standards so that the data can be published and used for promoting PNG timbers. The present report provides the machining testing results of 25 species where surface quality is of prime importance. Grading rules developed as part of this activity to provide a systematic basis for comparing the planing behaviour of different PNG species are also included to the present report (see Appendix 1).

Research Team

The present activity is the result of a very close collaboration between three organisations from Papua New Guinea and Australia: the PNG Forest Research Institute, the Timber and Forestry Training College, the PNG University of Technology and the University of Melbourne (Figure 1).

Figure 1. Students who participated in the machining trials at TFTC (Photo: Ravu Iru).

Machining Terminology

Torn grain - Machining defect formed by the splitting of wood along the grain below the level of the machined surface.

Fuzzy grain - Machining defect formed when wood fibres are torn up after having been severed resulting in wood filaments being bent upward and projected above the machined surface.

Raised grain - Machining defect happening when denser latewood is compressed into earlywood. Upon decompression, latewood rises above earlywood producing raised grain.

Chipped knife mark - Machining defect consisting of a longitudinal hill arising above the machined surface caused by cutting point been damaged or chipped.

Knife mark - Machining defect appearing as waves on the machined surface. They are usually well defined and occur at regular intervals.

Executive summary

An intensive testing program has been conducted to assess the mechanical properties and other processing characteristics (*e.g.* gluing, treatability) of 26 PNG timber species. The present activity report presents the machinability behaviour of 25 species sourced from the Morobe and West New Britain provinces, Papua New Guinea. Eight species have been harvested from plantations and 17 from secondary forests. The group included 3 softwoods and 22 hardwoods. One species, *Eucaliptus pellita*, could not be assessed because of lack of enough timber.

A total of 1,337 specimens and more than 3,600 linear meters of timber have been planed with a standard moulder machine and visually assessed by means of planing grading rules developed for the PNG wood processing industry. The grading system developed is based on the worst affected area of a machined surface (see Table 2 and Appendix 1). One or two people using sight and touch method have graded the planed surface. The defects checked for were torn grain, fuzzy grain, raised grain, chipped knife mark and knife mark. Between 32 to 76 specimens have been assessed per species with each specimen being dressed 3 times removing 1.6 mm every time.

A total of 18 wood species proved to machine very well with more than 90% boards being graded either "excellent and requiring very light sanding" or "good and requiring light sanding". Eight species from this group obtained a perfect score (*i.e.* 100%) across all three runs:

- Hoop Pine (*Araucaria cunninghamii*) **100%**
- Kwila (*Intsia bijuga*) **100%**
- Labula (*Anthocephalus chinensis*) **100%**
- Malas (*Homalium foetidum*) **100%**
- Pangium (*Pangium edule*) **100%**
- PNG Rosewood (*Pterocarpus indicus*) **100%**
- PNG Mersawa (*Anisoptera thurifera*) **100%**
- White Cheesewood (*Alstonia scholaris*) **100%**
- Erima (*Octomeles sumatrana*) **99%**
- Pencil Cedar (*Palaquium warbargianum*) **99%**
- PNG Basswood (*Endospermum medullosum*) **99%**
- Water Gum (*Syzygium spp.*) **99%**
- Kamarere (*Eucalyptus deglupta*) **98%**
- Blackbean (*Castanospermum australe*) **97%**
- Brown Terminalia (*Terminalia brassii*) **97%**
- PNG Quandong (*Elaeocarpus sphaericus*) **97%**
- Wau Beech (*Magnolia tsiampacca*) **94%**
- Caribbean Pine (*Pinus caribaea*) **91%**

A second group consisting of PNG Vitex (*Vitex cofassus*), Grey Canarium (*Canarium oleosum*), Heavy Hopea (*Hopea iriana*), Klinki Pine (*Araucaria hunsteinii*), and PNG Boxwood (*Xanthopyllum papuanum*) machined moderately well with averages across all three machining runs ranging between 70% and 90%. Two species, namely White albizzia (*Falcataria moluccana*) and Taun (*Pometia pinnata*), proved to machine with difficulty with average scores of 64% and 57%, respectively.

1. Introduction

Papua New Guinea (PNG) has a landmass covered with natural lowland rainforests. An estimated 60% of the total landmass is forested and customary owned. This forested land has commercial timber species identified and recognized by international markets, but other lesser-known species are also found. The PNG Development Strategic Plan for 2030 aims to increase the number of domestic processing on the harvested logs from 20% to 80% by encouraging and promoting downstream processing of round logs.

Wood is a unique material with a lengthy history in PNG. The natives have used this material primarily for shelter, tools, means of transport, and for fuel. In early days, stone axes and other means were used in processing the material. Central Province people in Southern part of PNG used stone axes to process low-density species such as Erima, Labula, PNG Basswood, and White Cheesewood to make long sailing Watercrafts famously known as *Lakatoi* which were used in the Hiri trade between Gulf of Papua. Processing and constructing such items could have taken natives long periods of time and extensive labour.

Today, the forestry sector contributes about 1.4 billion Papua New Guinean Kina a year (0.43 billion USD) in revenue and represents a major export earner for PNG economy (PNGFA report, 2018). In recent years, an increase in downstream processing of products from the forest sector such as sawn timber and veneer sheets or plywood panels has been observed, going from 8% to 21%. Availability of technical data and expansion of international markets could potentially create new avenues for the PNG forest industry and help producing more various products while creating more employment opportunities for Papua New Guineans.

Therefore, a study has been conducted using selected 25 PNG timber species to assess their machining characteristics *i.e.* their planing behaviour under cutting tools. Such data will then assist the PNG wood processing industry for an efficient processing and manufacturing of PNG timber species.

2. Materials and Methods

2.1 Harvesting and Milling

An exhaustive testing program including 25 selected PNG species has been divided into two batches to facilitate harvesting and specimens' preparation logistic. Each batch included 12 or 13 species from plantations and secondary forests (also known as regrowth forests) located in the Morobe and West New Britain provinces, PNG (Table 1). Eight species have been harvested from plantations and 17 from secondary forests. The group included 3 softwoods and 22 hardwoods.

A total of 130 trees, *i.e.* 5 trees per species, have been selected and harvested in accordance with ASTM D5536 (Figures 2 and 3). The trees have been selected based on the following selection criteria: 1) the tree had to be more than 15 years old after regrowth or planting; 2) all trees for a specific species had to be from the same forest area; 3) the selected trees had to be representative of the population, with good form and merchantable height. Following harvesting, the total merchantable height of each tree has been further cut into 3 to 4 m-long logs, labeled as per height from ground (*i.e.* bottom, middle, and top section), and milled. The milled sawn boards were then kiln-dried to 12% moisture content (Figure 4).

Figure 2. Selection of trees (Photos: Ravu Iru).

Table 1. PNG Studied Species Information

Species	Trade Name	Origin	Age (years)	ADD† at 12% MC (kg/m³)
Plantations (8 species)				
Araucaria cunninghamii	Pine, Hoop	Bulolo, Morobe	28	496
Araucaria hunsteinii	Pine, Klinki	Bulolo, Morobe	43	473
Castanospermum australe	Blackbean	Kimbe, West New Britain	17	792
Eucalyptus deglupta	Kamarere	Kimbe, West New Britain	29	562
Magnolia tsiampacca	Beech, Wau	Lae, Morobe	17	339
Pinus caribaea	Pine, Caribbean	Lae, Morobe	31	525
Pometia pinnata	Taun	Lae, Morobe	18	664
Terminalia brassii	Terminalia, Brown	Lae, Morobe	31	433
Secondary Forests / Regrowth (17 species)				
Alstonia scholaris	Cheesewood, White	Lae, Morobe	17 to 20	296
Anisoptera thurifera	Mersawa, PNG	Lae, Morobe	+20♠	685
Anthocephalus chinensis	Labula	Lae, Morobe	+20♠	418
Canarium oleosum	Canarium, Grey	Lae, Morobe	17 to 20	464
Elaeocarpus sphaericus	Quandong, PNG	Lae, Morobe	17 to 20	385
Endospermum medullosum	Basswood, PNG	Lae, Morobe	+20♠	356
Falcataria moluccana	Albizia, White	Lae, Morobe	+20♠	321
Homalium foetidum	Malas	Lae, Morobe	17 to 20	800
Hopea iriana	Hopea, Heavy	Lae, Morobe	+20♠	932
Intsia bijuga	Kwila	Lae, Morobe	+20♠	758
Octomeles sumatrana	Erima	Lae, Morobe	+20♠	276
Palaquium warbargianum	Cedar, Pencil	Lae, Morobe	17 to 20	381
Pangium edule	Pangium	Lae, Morobe	17 to 20	618
Pterocarpus indicus	Rosewood, PNG	Lae, Morobe	+20♠	557
Syzygium spp.	Gum, Water	Lae, Morobe	17 to 20	495
Vitex cofassus	Vitex, PNG	Lae, Morobe	+20♠	591
Xanthopyllum papuanum	Boxwood, PNG	Lae, Morobe	+20♠	718

♠ No exact records of age are available in the harvested area. Species estimated age is +20 years old.

† ADD: Air dry density.

Figure 3. Tree harvesting in the Morobe Province (Photos: Ravu Iru).

Figure 4. Timber milling at TFTC (left) and solar drying at PNG Unitech (right) (Photos: Ravu Iru).

2.2 Planing and Grading

The surface quality produced for all selected species was evaluated on a Weinig Profimat 22N moulder (Germany, Oberkochen, Figure 5). Timber specimens 50 mm x 50 mm x 900 mm were fed through and machined with the grain. The surface finish achieved was evaluated using a high-speed steel cutter material and a 30° grinding angle. A 1.6 mm cut was removed with a feeding speed of 6 m min^{-1} for a cutter-head speed of 5,478 rpm. Between 32 to 76 specimens have been assessed per species with each specimen being machined 3 times. A visual assessment of the surface quality has been conducted after each run using machining grading rules developed for the project and adapted from ASTM (2011).

Figure 5. Setting up of planer moulder (left) and planing trials (right) (Photos: Ravu Iru).

The grading system developed and used in the present activity is based on the worst affected area of a machined surface (Table 2, see appendix 1 for details). One or two people using sight and touch method graded the planed surface (Figure 6). The defects checked for were torn grain, fuzzy grain, raised grain, chipped knife mark and knife mark. A score was then assigned to the worst defect of each type. If no defects were present, then the sample was graded as A-Grade. Samples graded as A-Grade or B-Grade would be considered acceptable in furniture manufacturing and only requiring very light or light sanding.

Table 2. Category and definition for the surface grading rules.

Grade	Category	Definition
A	Excellent	Perfect surface with very light sanding
B	Good	Acceptable with light sanding
C	Fair	Acceptable with moderate sanding but undesirable
D	Poor	Unacceptable with defect requiring heavy sanding
E	Very Poor	Unacceptable with defect beyond repair

Figure 6. Visual assessment and grading of planed surfaces (Photo: Benoit Belleville)

3. Results and Discussion

A total of 1,337 specimens from 25 species or approximately 3,600 linear meters have been planed and visually assessed. An overview showing the average percentages of boards graded as "excellent" or "good" where an excellent surface is considered requiring "very light sanding" and a good surface requiring "light sanding" is presented in Table 3. A total of 18 wood species proved to machine very well *i.e.* provided an average score of boards graded as "excellent" or "good" higher than 90%. Eight species obtained a perfect score of 100%. A second group consisting of PNG Vitex, Grey Canarium, Heavy Hopea, Klinki Pine, and PNG Boxwood machined moderately well with averages ranging between 70% and 90%. Two species, namely White Albizia and Taun, proved to machine with difficulty.

Table 3. Summary table of machining characteristics for studied species.

Machining Classes	Species	Average of all 3 runs (%[a])
Machine Very Well Average score of A-Grade and B-Grade boards after 3 runs higher than 90%.	PNG Rosewood	100
	PNG Mersawa	100
	Labula	100
	Kwila	100
	Malas	100
	Pangium	100
	Hoop Pine	100
	White Cheesewood	100
	Erima	99
	Water Gum	99
	PNG Basswood	99
	Pencil Cedar	99
	Kamarere	98
	Brown Terminalia	97
	PNG Quandong	97
	Blackbean	97
	Wau Beech	94
	Caribbean Pine	91
Machine Moderately Well Average score of A-Grade and B-Grade boards after 3 runs between 70-90%.	PNG Vitex	90
	Grey Canarium	89
	Heavy Hopea	89
	Klinki Pine	84
	PNG Boxwood	70
Difficult to Machine Average score of A-Grade and B-Grade boards after 3 runs lower than 70%.	White Albizia	64
	Taun	57

[a] Percentages calculated based on total number of boards graded as "excellent" or "good" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding"

Taun

Taun (*Pometia pinnata*) is a moderately heavy wood species (ADD of 664 kg/m^3) which proved to be difficult to machine. Only 68% of machined boards offered a surface suitable for wood manufacturing following the 3rd and final run (Table 4). When including all 3 runs, 57% of machined boards provided a surface considered excellent or good (Table 3). The main reasons for downgrading were torn grain (39%) and fuzzy grain (39%) followed by raised grain (33%) (Table 5).

Table 4. Percentage of Taun (*Pometia pinnata*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**40%**	**63%**	**68%**
Tangential face only	NA	NA	NA
Radial face only	30%	65%	70%
Diagonal face only	52%	61%	65%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 5. Percentage of most common causes degrade of Taun (*Pometia pinnata*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**39%**	**39%**	**33%**	**8%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	49%	42%	33%	9%	0%
Diagonal face only	23%	32%	32%	6%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

PNG Rosewood

PNG Rosewood (*Pterocarpus indicus*) showed to be a species very easy to work. With an average air dry density of 557 kg/m^3 at 12% moisture content, PNG Rosewood constantly offered an excellent or good surface across all 3 runs (Table 6). No planing defects have been observed during the machining trials (Table 7).

Table 6. Percentage of PNG Rosewood (*Pterocarpus indicus*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**100%**	**100%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	100%	100%	100%
Diagonal face only	100%	100%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 7. Percentage of most common causes degrade of PNG Rosewood (*Pterocarpus indicus*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**0%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	0%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

PNG Boxwood

PNG Boxwood (*Xanthopyllum papuanum*) has a moderately heavy wood (*i.e.* ADD 718 kg/m^3) which tend to be difficult to machine. Across all 3 runs, PNG Boxwood provided a surface quality suitable for wood manufacturing 70% of the time (Tables 3 and 8). Extra attention can be necessary to ensure that the cutting tools remain sharp as highlighted with results from the 3rd run. Raised grain and chipped knife marks were two common manufacturing defects observed during the machining trials (Table 9).

Table 8. Percentage of PNG Boxwood (*Xanthopyllum papuanum*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**93%**	**98%**	**20%†**
Tangential face only	NA	NA	NA
Radial face only	81%	94%	25%
Diagonal face only	97%	100%	18%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding". † An important proportion of raised grain and chip mark resulted in many fair and poor grades from the 3rd run.

Table 9. Percentage of most common causes degrade of PNG Boxwood (*Xanthopyllum papuanum*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**0%**	**7%**	**7%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	0%	19%	19%	0%
Diagonal face only	0%	0%	3%	3%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Labula

Labula's (*Anthocephalus chinensis*) relatively low-density wood (air dry density of 418 kg/m^3 at 12%) was very easy to work using the moulder machine. Labula constantly offered an excellent or good surface across all 3 runs (Table 10). No planing defects have been observed during the machining trials (Table 11).

Table 10. Percentage of Labula (*Anthocephalus chinensis*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**100%**	**100%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	100%	100%	100%
Diagonal face only	100%	100%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 11. Percentage of most common causes degrade of Labula (*Anthocephalus chinensis*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**0%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	0%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

PNG Vitex

PNG Vitex (*Vitex cofassus*) is a medium-density species (591 kg/m^3) which machined moderately well. After the 3rd and final run, all dressed boards provided either an excellent or a good quality surface (Tables 12). When considering all 3 runs, 90% of all boards machined proved to be suitable for wood manufacturing with fuzzy grain being the main reason for downgrading, especially following the 1st run (Tables 3 and 13).

Table 12. Percentage of PNG Vitex (*Vitex cofassus*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**78%**	**91%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	77%	87%	100%
Diagonal face only	78%	96%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 13. Percentage of most common causes degrade of PNG Vitex (*Vitex cofassus*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**4%**	**15%**	**6%**	**2%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	16%	6%	3%	0%
Diagonal face only	9%	13%	4%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Erima

Erima (*Octomeles sumatrana*) has a low-density wood *i.e.* ADD 276 kg/m^3 which was very easy to work. Across all 3 runs, Erima always provided a surface quality suitable for wood manufacturing (Table 14). No manufacturing defects requiring more than a very light sanding have been observed during the machining trials (Table 15).

Table 14. Percentage of Erima (*Octomeles sumatrana*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**100%**	**100%**	**98%**
Tangential face only	NA	NA	NA
Radial face only	100%	100%	100%
Diagonal face only	100%	100%	94%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 15. Percentage of most common causes degrade of Erima (*Octomeles sumatrana*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**0%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	0%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

PNG Mersawa

Although PNG Mersawa (*Anisoptera thurifera*) is moderately heavy with an air dry density of 685 kg/m^3, it proved to be a very easy wood to work. PNG Mersawa constantly offered an excellent or good surface across all 3 runs (Table 16). No planing defects have been observed during the machining trials (Table 17).

Table 16. Percentage of PNG Mersawa (*Anisoptera thurifera*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**100%**	**100%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	100%	100%	100%
Diagonal face only	100%	100%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 17. Percentage of most common causes degrade of PNG Mersawa (*Anisoptera thurifera*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**0%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	0%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

White Albizia

White Albizia (*Falcataria moluccana*) is a low-density wood species (ADD of 321 kg/m^3) which proved to be difficult to machine. A total of 83% of all machined boards offered a surface suitable for wood manufacturing following the 3rd and final run (Table 18). When including all 3 runs, only 64% of all machined boards provided a surface quality considered excellent or good (Table 3). The main reasons for downgrading were fuzzy grain (32%) followed by raised grain (28%) and torn grain (9%) (Table 19).

Table 18. Percentage of White Albizia (*Falcataria moluccana*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**49%**	**60%**	**83%**
Tangential face only	NA	NA	NA
Radial face only	41%	58%	81%
Diagonal face only	58%	65%	88%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 19. Percentage of most common causes degrade of White Albizia (*Falcataria moluccana*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**9%**	**32%**	**28%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	38%	34%	0%	0%
Diagonal face only	21%	25%	21%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

PNG Basswood

PNG Basswood (*Endospermum medullosum*), a low-density species at 356 kg/m^3, machined very well. After the 3rd and final run, all boards dressed provided either an excellent or a good surface quality (Tables 20). When considering all 3 runs together, 99% of boards machined prove to be suitable for wood manufacturing with 2% being downgraded because of fuzzy grain after the 1st run (Tables 3 and 21).

Table 20. Percentage of PNG Basswood (*Endospermum medullosum*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**98%**	**100%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	97%	100%	100%
Diagonal face only	100%	100%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 21. Percentage of most common causes degrade of PNG Basswood (*Endospermum medullosum*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**2%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	3%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Wau Beech

Wau Beech (*Magnolia tsiampacca*) is a low-density species (356 kg/m^3) which machined fairly well. After the 3rd and final run, all boards dressed provided either an excellent or a good surface quality (Tables 22). When considering all 3 runs together, 94% of boards machined prove to be suitable for wood manufacturing with 17% being downgraded following the 1st run because of fuzzy grain (Tables 3 and 23).

Table 22. Percentage of Wau Beech (*Magnolia tsiampacca*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**83%**	**100%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	80%	100%	100%
Diagonal face only	88%	100%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 23. Percentage of most common causes degrade of Wau Beech (*Magnolia tsiampacca*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**17%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	20%	0%	0%	0%
Diagonal face only	0%	13%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Heavy Hopea

Heavy Hopea (*Hopea iriana*) machined fairly well despite being a very heavy wood species with an average air dry density of 932 kg/m^3. After the 3rd and final run, 96% of all boards dressed provided either an excellent or a good surface quality (Table 24). When considering all 3 runs together, 89% of boards machined prove to be suitable for wood manufacturing (Table 3). However, the very high density of Heavy Hopea wood can be hard on cutting tools and cause a significant proportion of chipped knife marks especially when high volumes of wood are processed (Table 25).

Table 24. Percentage of Heavy Hopea (*Hopea iriana*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**85%**	**85%**	**96%**
Tangential face only	NA	NA	NA
Radial face only	84%	84%	95%
Diagonal face only	86%	86%	97%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 25. Percentage of most common causes degrade of Heavy Hopea (*Hopea iriana*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**0%**	**0%**	**15%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	0%	0%	16%	0%
Diagonal face only	0%	0%	0%	14%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Kwila

Kwila (*Intsia bijuga*), a moderately heavy species with an air dry density of 758 kg/m^3 at 12% moisture content, showed to be a very easy species to work. Kwila wood continuously offered an excellent or good surface across all 3 runs (Table 26). No planing defects could be observed during the machining trials (Table 27).

Table 26. Percentage of Kwila (*Intsia bijuga*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**100%**	**100%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	100%	100%	100%
Diagonal face only	100%	100%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 27. Percentage of most common causes degrade of Kwila (*Intsia bijuga*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**0%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	0%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Kamarere

Kamarere (*Eucalyptus deglupta*) showed to be a species easy to work. With an average air dry density of 562 kg/m^3 at 12% moisture content, Kamarere offered an excellent or good surface across all 3 runs 98% of the time with fuzzy grain being the reason for downgrading (Tables 28 and 29).

Table 28. Percentage of Kamarere (*Eucalyptus deglupta*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**98%**	**98%**	**98%**
Tangential face only	NA	NA	NA
Radial face only	97%	97%	97%
Diagonal face only	100%	100%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 29. Percentage of most common causes degrade of Kamarere (*Eucalyptus deglupta*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**2%**	**0%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	3%	0%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Blackbean

Blackbean (*Castanospermum australe*) machined very well despite being a heavy wood species with an average air dry density of 792 kg/m^3. After the 3rd and final run, all boards dressed provided either an excellent or a good surface quality (Table 30). When considering all 3 runs together, 97% of boards machined prove to be suitable for wood manufacturing with torn grain being the reason for downgrading (Tables 3 and 31).

Table 30. Percentage of Blackbean (*Castanospermum australe*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**94%**	**98%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	93%	100%	100%
Diagonal face only	95%	95%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 31. Percentage of most common causes degrade of Blackbean (*Castanospermum australe*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**6%**	**0%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	7%	0%	0%	0%	0%
Diagonal face only	5%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Malas

Malas (*Homalium foetidum*) showed to be a species very easy to machine even though being a relatively heavy wood with an average air dry density of 800 kg/m^3. Malas constantly provided an excellent or good surface across all 3 runs (Table 32). No planing defects have been observed during the machining trials (Table 33).

Table 32. Percentage of Malas (*Homalium foetidum*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**100%**	**100%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	100%	100%	100%
Diagonal face only	100%	100%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 33. Percentage of most common causes degrade of Malas (*Homalium foetidum*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**0%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	0%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Pangium

Pangium (*Pangium edule*) has a moderately heavy wood (*i.e.* ADD 618 kg/m^3) which was very easy to work. Across all 3 runs, Pangium always provided a surface quality suitable for wood manufacturing (Table 34). No manufacturing defects requiring more than a very light sanding have been observed during the machining trials (Table 35).

Table 34. Percentage of Pangium (*Pangium edule*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**100%**	**100%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	100%	100%	100%
Diagonal face only	100%	100%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 35. Percentage of most common causes degrade of Pangium (*Pangium edule*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**0%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	0%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Water Gum

Water Gum (*Syzygium spp.*) showed to be a species very easy to work. With an average air dry density of 495 kg/m^3 at 12% moisture content, Water Gum constantly offered an excellent or good surface across all 3 runs (Table 36). No planing defects could be observed during the machining trials (Table 37).

Table 36. Percentage of Water Gum (*Syzygium spp.*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**100%**	**98%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	100%	97%	100%
Diagonal face only	100%	100%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 37. Percentage of most common causes degrade of Water Gum (*Syzygium spp.*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**0%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	0%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Brown Terminalia

Brown Terminalia (*Terminalia brassii*), a relatively low-density species at 433 kg/m^3, machined very well. After the 3rd and final run, 96% of all boards dressed provided either an excellent or a good surface quality (Tables 38 and 39). When considering all 3 runs together, 97% of boards machined prove to be suitable for wood manufacturing (Table 3).

Table 38. Percentage of Brown Terminalia (*Terminalia brassii*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**100%**	**96%**	**96%**
Tangential face only	NA	NA	NA
Radial face only	100%	98%	95%
Diagonal face only	100%	90%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 39. Percentage of most common causes degrade of Brown Terminalia (*Terminalia brassii*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**0%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	0%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

White Cheesewood

White Cheesewood (*Alstonia scholaris*) has a low-density wood (*i.e.* ADD 296 kg/m^3) which was very easy to work. Across all 3 runs, White Cheesewood always provided a surface quality suitable for wood manufacturing (Table 40). No manufacturing defects requiring more than a very light sanding have been observed during the machining trials (Table 41).

Table 40. Percentage of White Cheesewood (*Alstonia scholaris*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**100%**	**100%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	100%	100%	100%
Diagonal face only	100%	100%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 41. Percentage of most common causes degrade of White Cheesewood (*Alstonia scholaris*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**0%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	0%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Pencil Cedar

Pencil Cedar (*Palaquium warbargianum*), a low-density species at 381 kg/m^3, machined very well. After the 3rd and final run, all boards dressed provided either an excellent or a good surface quality (Tables 42). When considering all 3 runs together, 99% of boards machined proved to be suitable for wood manufacturing with 2% being downgraded because of fuzzy grain after the 1st run (Tables 3 and 43).

Table 42. Percentage of Pencil Cedar (*Palaquium warbargianum*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**98%**	**98%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	98%	98%	100%
Diagonal face only	100%	100%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 43. Percentage of most common causes degrade of Pencil Cedar (*Palaquium warbargianum*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**2%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	2%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Grey Canarium

Grey Canarium (*Canarium oleosum*) showed to be a species moderately easy to work. With an average air dry density of 464 kg/m^3 at 12% moisture content, Grey Canarium offered an excellent or good surface across all 3 runs 89% of the time with fuzzy grain (12%) and raised grain (2%) being the main reasons for downgrading (Tables 3, 44 and 45).

Table 44. Percentage of Grey Canarium (*Canarium oleosum*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**86%**	**90%**	**92%**
Tangential face only	NA	NA	NA
Radial face only	88%	90%	95%
Diagonal face only	80%	90%	80%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 45. Percentage of most common causes degrade of Grey Canarium (*Canarium oleosum*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**12%**	**2%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	10%	3%	0%	0%
Diagonal face only	0%	20%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

PNG Quandong

PNG Quandong (*Elaeocarpus sphaericus*) is a low-density (385 kg/m^3 at 12% moisture content) species should showed to be relatively easy to work. PNG Quandong offered an excellent or good surface across all 3 runs 97% of the time with fuzzy grain being the reason for downgrading (Tables 3, 46 and 47). All machined boards offered a surface quality suitable for wood manufacturing after the 3rd and final run.

Table 46. Percentage of PNG Quandong (*Elaeocarpus sphaericus*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**96%**	**96%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	95%	97%	100%
Diagonal face only	100%	92%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 47. Percentage of most common causes degrade of PNG Quandong (*Elaeocarpus sphaericus*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**4%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	5%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Caribbean Pine

Caribbean Pine (*Pinus caribaea*) is a medium-density softwood species (525 kg/m^3) which machined fairly well. After the 3rd and final run, all boards dressed presented either an excellent or a good surface quality (Tables 48). When considering all 3 runs together, 91% of boards machined proved to be suitable for wood manufacturing with torn and fuzzy grain being the main reasons for downgrading after the 1st and 2nd runs (Tables 3 and 49).

Table 48. Percentage of Caribbean Pine (*Pinus caribaea*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**87%**	**85%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	88%	88%	100%
Diagonal face only	86%	82%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 49. Percentage of most common causes degrade of Caribbean Pine (*Pinus caribaea*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**4%**	**11%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	4%	13%	0%	0%	0%
Diagonal face only	5%	9%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Hoop Pine

Hoop Pine (*Araucaria cunninghamii*) showed to be a species very easy to work. With an average air dry density of 496 kg/m^3 at 12% moisture content, Hoop Pine constantly offered an excellent or good surface across all 3 runs (Table 50). No planing defects could be observed during the machining trials (Table 51).

Table 50. Percentage of Hoop Pine (*Araucaria cunninghamii*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**100%**	**100%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	100%	100%	100%
Diagonal face only	100%	100%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 51. Percentage of most common causes degrade of Hoop Pine (*Araucaria cunninghamii*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**0%**	**0%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	0%	0%	0%	0%	0%
Diagonal face only	0%	0%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

Klinki Pine

Klinki Pine (*Araucaria hunsteinii*) showed to be a species moderately easy to work. With an average air dry density of 473 kg/m^3 at 12% moisture content, Klinki Pine offered an excellent or good surface across all 3 runs 84% of the time (Tables 3 and 52). All board presented a surface quality suitable for wood manufacturing following the 3rd and final run. Fuzzy grain (31%) and torn grain (16%) accounted for more than 30% of the boards being downgraded after the 1st run (Table 53).

Table 52. Percentage of Klinki Pine (*Araucaria hunsteinii*) sample boards achieving a satisfactory machining surface grade per run.

	1st Run	2nd Run	3rd Run
Overall (combined)	**69%**	**84%**	**100%**
Tangential face only	NA	NA	NA
Radial face only	73%	86%	100%
Diagonal face only	60%	80%	100%

Wood material removed per run: 1.6 mm; Percentages calculated based on total number of boards graded as "*excellent*" or "*good*" where an "excellent" surface is considered requiring "very light sanding" and a "good surface" requiring "light sanding".

Table 53. Percentage of most common causes degrade of Klinki Pine (*Araucaria hunsteinii*) samples boards after visual assessment following the first run.

	Torn Grain	Fuzzy Grain	Raised Grain	Chip Mark	Knife Mark
Overall (combined)	**16%**	**31%**	**0%**	**0%**	**0%**
Tangential face only	NA	NA	NA	NA	NA
Radial face only	9%	27%	0%	0%	0%
Diagonal face only	30%	40%	0%	0%	0%

Wood material removed: 1.6 mm; Percentages calculated based on total number of boards graded as "*Fair*", "*Poor*" or "*Very Poor*" and requiring "moderate" or "*heavy sanding*" or considered "*beyond repair*" divided by total number of boards assessed.

4. Conclusion

The overall aim of the project was to increase the contribution that utilisation of forest resources makes to national and local economies, including landowners and processors, through the development of domestic value-added wood processing methods. The objective of the present activity was to enhance the knowledge of wood properties and processing characteristics of PNG timbers and more specifically the processing characteristics required to successfully produce value-added products for PNG and export markets.

An intensive machining testing program has been conducted to assess the planing behaviour of 25 species sourced from the Morobe and West New Britain provinces, Papua New Guinea. Eight species have been selected from plantations and 17 from secondary forests. The group included 3 softwoods and 22 hardwoods. The surface quality has been evaluated using standard moulder equipment. Planing grading rules have also been developed and used as part of present activity 1.6. The grading rules were based on the worst affected area of a machined surface and provided a systematic basis for comparing the planing behaviour of different species where surface quality is of prime importance.

A total of 1,337 specimens from 25 species or approximately 3,600 linear meters have been planed and visually assessed. Eighteen wood species proved to machine very well *i.e.* provided an average score of boards graded either as "excellent" or "good" above 90%. Eight species obtained a perfect score of 100%. Another group consisting of PNG Vitex, Grey Canarium, Heavy Hopea, Klinki Pine, and PNG Boxwood machined moderately well with averages ranging between 70% and 90%. Two species, namely White Albizia and Taun, proved to machine with difficulty with average scores below 70%. Where most common machining defects observed consisted in fuzzy grain, torn grain or raised grain, some higher density species also incurred chipped knife marks. Overall, most machining defects encountered in the present study can be minimised with the introduction of regular sharpening schedules and training to woodworkers on how to identify machining defects as part of a quality control program.

List of references

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PNGFA (2018) Internal Report. Papua New Guinea Forestry Authority (PNGFA)

Appendix 1 – Surface Defects & Planing Grading Rules

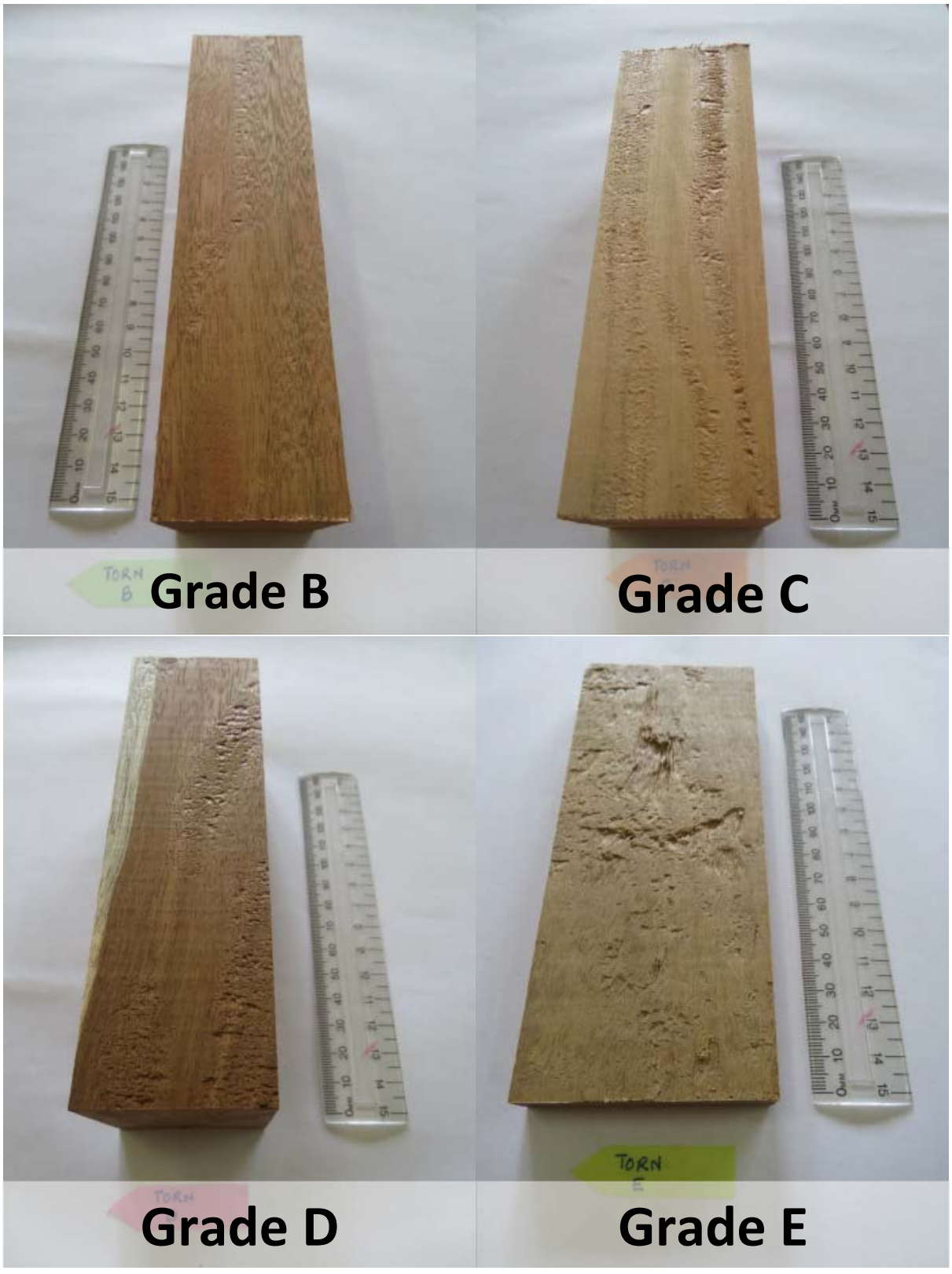


Figure 1. Torn Grain Grades B to E

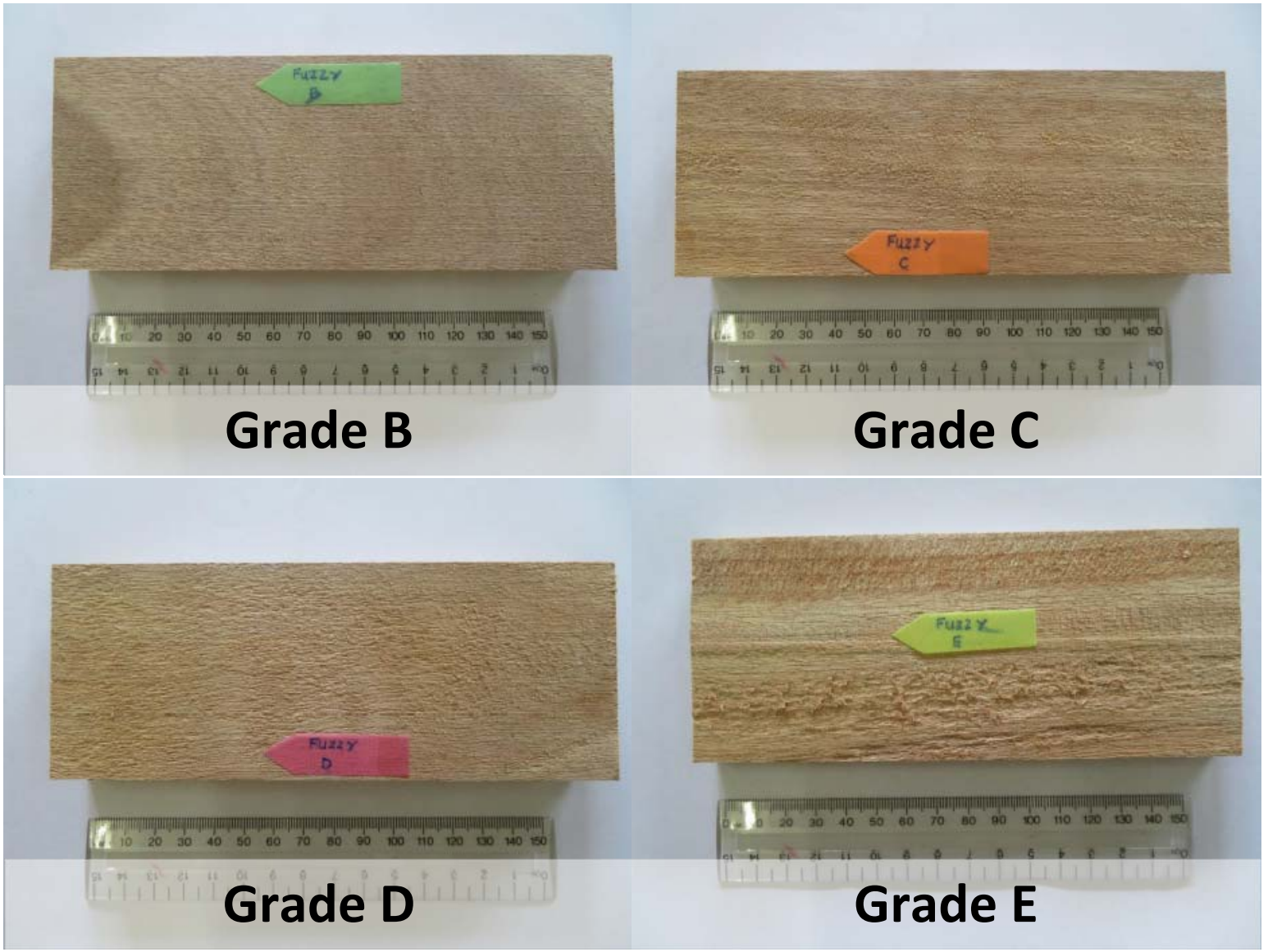


Figure 2. Fuzzy Grain Grades B to E

Figure 3. Raised Grain Grades B to E

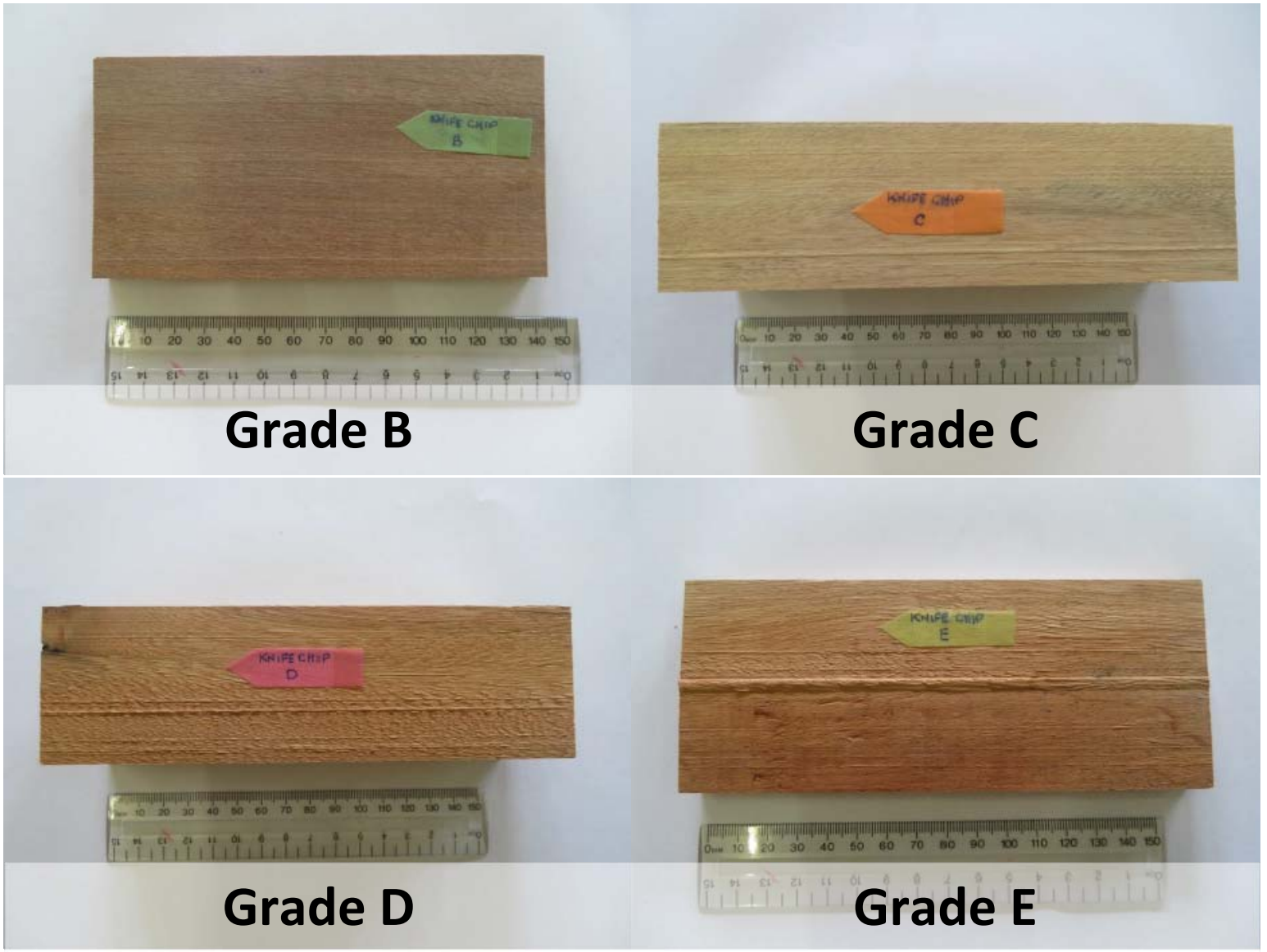


Figure 4. Knife Chip Mark Grades B to E

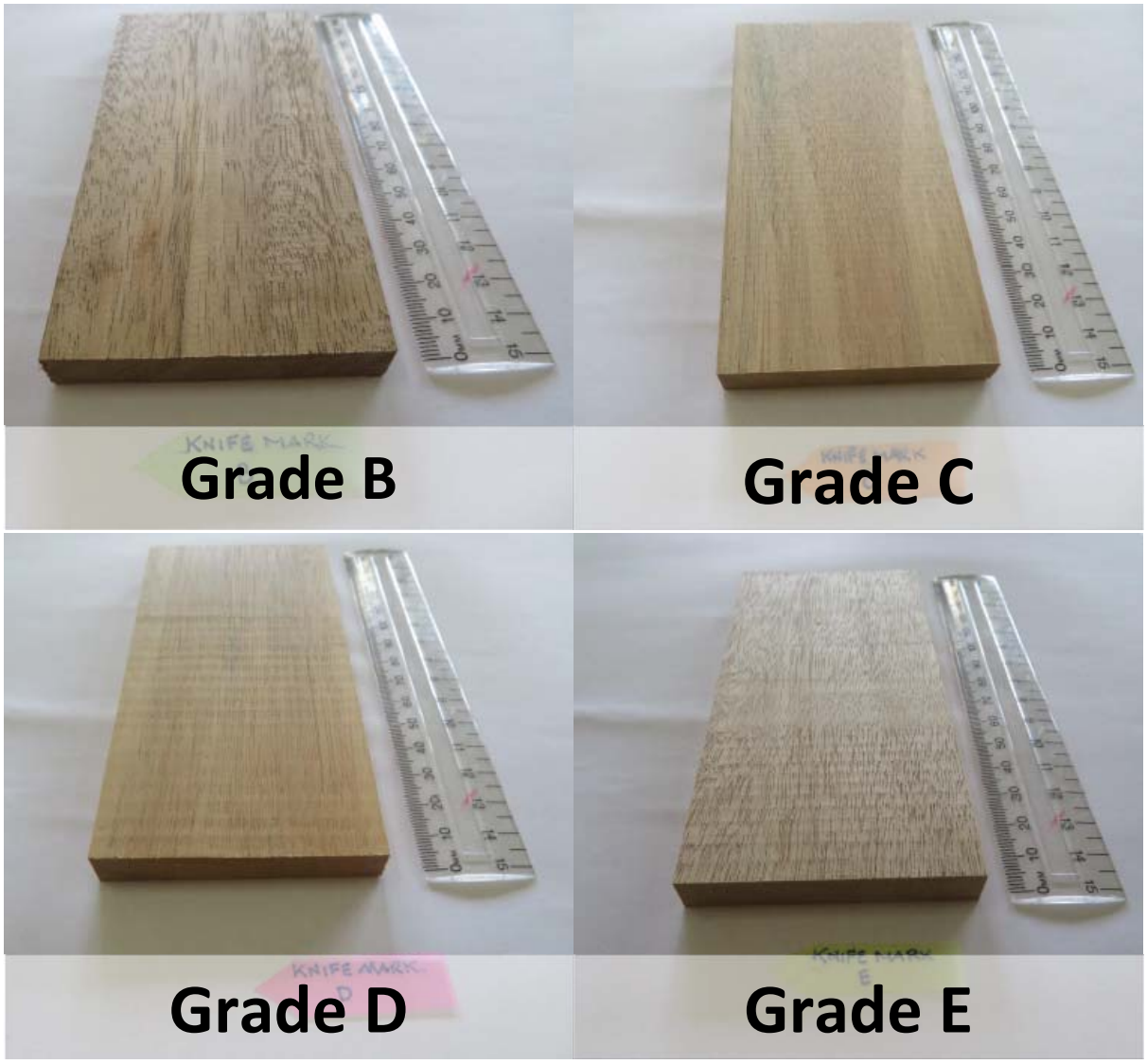
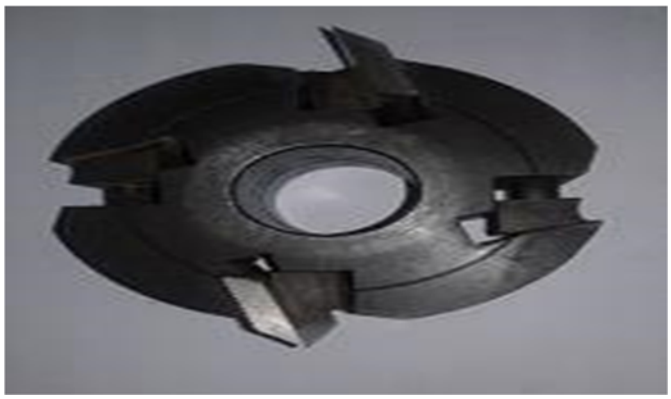


Figure 5. Knife Mark Grades B to E

Appendix 2 – Cutting Tools Details

High-speed steel cutting tools (4) with serrated back used for testing. Composition: Iron (76.4%), Tungsten (18%), Chromium (4%), Vanadium (1%), Carbon (0.4%), Other elements (0.2%).



Weinig Rondamat 950 in-head grinder used to sharpen the cutting tools to a 30 ° grinding angle.

Tooling – The standard cylindrical serrated tooling diameter of 122 mm with two cutting tool inserted. The minimum cutting circles for each cutting tool mounted taken as; Right side with 138.35 mm, Left side with 141.34 mm, Top with 136.93 mm and the Bottom cutting tool with 150.30 mm.

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