

Yield Performance of Locally Selected Cocoa Clones in North Luwu

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Abstract

Participatory selection in North Luwu District has selected some local cocoa clones, of which MCC 01 and MCC 02 are the most promising to be developed as clonal materials. This research has the objective to study stability yield performance of these clones that enable be characterized of their potency as the basis for recommendation. Observation was carried out in 35 selected-farms be differentiated according to clone type, namely MCC 01, MCC 02 and Sulawesi 01 (control) and year of planting. These farms were established at the main area of cocoa in North Luwu. The assessed variables were number of pods, yield components, resistance to cocoa pod borer (CPB), vascular-streak dieback (VSD) and phytophthora pod rot (PPR). Data were recorded through 20 sampled-trees per farm in the period of April 2013 to April 2014 with monthly basis assessment. Data were analyzed according to Eberhart & Russel method to perform stability parameters of the yield. The results indicated that these clones were stable in performing yield potency among plant age. MCC 01 and MCC 02 performed yield potency of 3,682 kg/ha/yr and 3,132 kg/ha/yr, respectively higher, than Sulawesi 01 of 2,772 kg/ha/yr. MCC 01 was moderate resistance to CPB and VSD and resistance to PPR, however MCC 02 was resistance to CPB, VSD and PPR. Referring to that potency, MCC 01 and MCC 02 were legally recommended as clonal materials for farmers, restricted at the agroclimatic area similar to the condition in North Luwu.

Keywords: local variety, cocoa clones, yield performance, North Luwu, *Theobroma cacao* L.

INTRODUCTION

Sulawesi is well known as the center of cocoa production area in Indonesia which contributes more than 50% of national production (Ditjenbun, 2012). The highest contribution to the production derived from South Sulawesi specially produced in Luwu region. Cocoa plays significant role on economic growth in South Sulawesi, whereas its contribution to gross domestic product was the second highest after nickel. Besides, cocoa significantly contributes to household earning for about 300.000 families. Cocoa sustainability is the main issue on stabilizing economic growth in South

Sulawesi, however there are some problems which cause yield loss. The main problems on cocoa plantation in South Sulawesi are pests and diseases, decreasing soil fertility and plant aging.

Some cooperative efforts between farmers and government in addressing the problems by rehabilitating the unproductive trees using side grafting method has been carried out. Recommended clones for side grafting are Sulawesi 01 and Sulawesi 02 which are adaptive in the agro-climatic condition of Sulawesi and resistant to vascular-streak dieback (VSD). Side grafting and implementation of good agricultural practices (GAP) increased cocoa productivity fantastically

which promoted farmers to adopt this technique. This program was initiated since early 2000's (Susilo & Suhendi, 2006) which then broaden the scope of this rehabilitation program after Indonesia Government launched a program of the national movement to increase cocoa productivity and quality known as GERNAS program. Through this program, unproductive trees were rehabilitated using side grafting method in the area of 245,000 ha or covering 15.1% of the total cocoa area in Indonesia (Ditjenbun, 2008).

Success story on the cocoa rehabilitation using high yielding clones has triggered some innovative farmers, especially in North Luwu District to identify promising trees derived from hybrid seedlings then propagated clonally to select high yielding genotypes. Criteria of the farmer's selection are based on the yield components and resistance to endemic pests and diseases, such as VSD, cocoa pod borer (CPB) and *Phytophthora* pod rot (PPR). The local genetic materials of cocoa which mostly be planted in Sulawesi were derived from hybrid seedlings through a project in 1980's. The hybrids were generated from outcrossing between the selected clones as parents such as TSH 858, TSH 908, Sca 06, Sca 12, IMC 67, UIT 1, ICS 60, Pa 300, Pa 310, GC 29 (Susilo *et al.*, 2013) from which many genetic recombinations were inherited for selection. Participatory selection to select the best progenies can be carried out in collaboration with farmers, extension officers and breeders as the implementation of recurrent selection (Pokoe *et al.*, 2009). Susilo (2013) identified at least 6 locally selected clones in North Luwu that had been developed by farmers for clonal materials. Of those clones, there are 2 most-preferred clones which perform high yielding, big-bean size and more tolerant to endemic pests and diseases, namely M01 and 45 as their clone codes. Those clones have been registered as local variety authorized by the Government

of North Luwu District then renamed with MCC 01 and MCC 02, respectively. The utilization of these clones as clonal materials until outside North Luwu area confirms the high potency of these genetic resources to be developed as an agricultural technology suitable for farmers with similar agroclimate condition.

Factually in the field those clones are performing high yielding potency and more tolerance to endemic pest and diseases that mostly preferred by farmers as clonal material other. Although the two clones perform higher yielding potency than the previously recommended clones of Sulawesi 01 and Sulawesi 02, they are not yet formally recommended as cocoa planting materials. A research to study yield performance of MCC 01 and MCC 02 was carried out through a collaboration research between Indonesian Coffee and Cocoa Research Institute (ICCRI) and the Government of North Luwu District in order to fulfill the requirement procedure for releasing the locally selected clones as planting material. This paper discusses the results of the yield potency study of MCC 01 and MCC 02 compared with other released clones and justified for being recommended as cocoa planting material.

MATERIALS AND METHODS

The tested cocoa clones were the two most preferred locally selected clones in North Luwu District, namely MCC 01 (clone code M01), MCC 02 (clone code 45) and Sulawesi 01 used as control (a released cocoa clone based on Degree of Ministry of Agriculture No.694/Kpts/SR.120/12/2008). The clones of MCC 01 and MCC 02 were registered as local variety authorized by the Government of North Luwu District with the registration number of No.54/PVL/2013 and No.55/PVL/2013 respectively and the historical background of which was reported by Susilo (2013).

Yield performance observations were carried out through the selected farms in the North Luwu District area. It was situated in the low land area (maximum 300 m above sea level), type A-B of climatic condition according to the classification of Schmidt & Ferguson (2 dry-months, 7–9 wet-months), type of soil Ultisol, Inceptisol, Entisol. The sampled farms were differentiated according to the clone's type (MCC 01, MCC 02 and Sulawesi 01), year of planting/grafting (plant age) and repetition of the similar condition of the farms as replications. Thirty five farms were selected distributed through the Sub District of Masamba, Malangke, Baebunta, Tanalili, Sukamaju, Mappedeceng and Sabbang (Table 1). Year of planting varied from 2006 to 2012 when the plants were propagated by side grafting or top grafting. In each of the sampled farm 20 normal trees were selected for assessing the yield component (pod number, number of beans per pod, and dry bean weight), incidence of VSD, CPB and PPR. All of the selected farms were managed according to the farmer's management and classified as good farms.

Yield potency of the clones were assessed based on number of pods per tree in monthly basis then converted to yield potency per hectare (population of cocoa trees was assumed 1,100 trees/ha) in the period of April 2013 to March 2014. Yield data are the conversion of pod number divided by pod index which is number of pods required to produce one kilogram of dry beans. Bean count which is number of beans per 100 g of dry bean at 7% moisture content and number of bean per pod were needed to support yield data.

Fat analysis was conducted in the laboratory for cocoa quality of PT. Mars Symbioscience in Makassar. The method used a spectrophotometer with infra red (Foss System II 6500 scanning spectro-

Table 1. The observed farms for evaluation the yield stability performance of MCC 01 and MCC 02 in North Luwu, South Sulawesi

Farm location (village, sub district)	Farmer names	Clone	Year of planting
Tingkara-Malangke	Andi Muliadi	MCC 02	2006
Ujung Matajang- Mappedeceng	Mindarwis	MCC 01	2007
Tingkara-Malangke	Abd Rahim	MCC 01	2007
Ujung Matajang- Mappedeceng	Mindarwis	Sulawesi 01	2007
Pombakka-Masamba	Muh. Hazlan	MCC 01	2008
Bungadidi-Tanalili	Marsuki	MCC 01	2008
Tingkara-Malangke	Abd Rahim	MCC 01	2008
Putemata-Malangke	Sanuddin	MCC 02	2008
Sumber Wangi- Mappedeceng	Andi Farida	MCC 02	2008
Bungadidi-Tanalili	Rahman	MCC 02	2008
Sumber Wangi- Mappedeceng	Andi Farida	Sulawesi 01	2008
Bungadidi-Tanalili	Marsuki	Sulawesi 01	2008
Polejiwa- Malangke Barat	Kahariman	Sulawesi 01	2008
Pongo-Masamba	Idin Rasyid	MCC 01	2009
Ujung Matajang- Mappedeceng	Lamang	MCC 01	2009
Sumber Baru-Sukamaju	Ambar	MCC 01	2009
Banyuwangi- Sukamaju	Rubiyanti/ Dulkarim	MCC 02	2009
Bungadidi-Tanalili	Marsuki	MCC 02	2009
Pongo-Masamba	Kabir	MCC 02	2009
Banyuwangi- Sukamaju	Rubiyanti/ Dulkarim	MCC 01	2009
Pongo-Masamba	Idin Rasyid	Sulawesi 01	2009
Ujung Matajang- Mappedeceng	Lamang	Sulawesi 01	2009
Banyuwangi- Sukamaju	Rubiyanti/ Dulkarim	Sulawesi 01	2009
Pongo-Masamba	Salim	MCC 01	2010
Palandan-Baebunta	Sarwan	MCC 01	2010
Bungadidi-Tanalili	Marsuki	MCC 01	2010
Palandan-Baebunta	Halim	MCC 02	2010
Palandan-Baebunta	Irja	MCC 02	2010
Polewali-Baebunta	Hasrul Amir	MCC 02	2010
Karianggo-Baebunta	Beddu Jamma	Sulawesi 01	2010
Sumber Baru- Sukamaju	Ambar	Sulawesi 01	2010
Ujung Matajang- Mappedeceng	Herman	Sulawesi 01	2010
Ujung Matajang- Mappedeceng	Herman	MCC 02	2011
Pekendekan- Sabbang	Dg. Matinring	MCC 01	2012
Pekendekan- Sabbang	Dg. Matinring	MCC 02	2012

photometer, NIR Systems Inc. Silver Springs MD) at the wave length of 400–2500 nm interval 2 nm. Calibration of the equipment was carried using modified partial least square regression. Data of fat content then classified high (>55%), moderate (52.3–55%) and low (\leq 52.2%) according to Khan *et al.* (2008).

Evaluation for CPB resistance was observed based on the severity damage of pod sample with criteria healthy (no symptom), light (unextractable beans <10%), moderate (unextractable beans 10–<50%) and heavy (unextractable beans >50%). The total assessed samples were 5,749 pods of MCC 01; 4,917 pods of MCC 02 and 6,981 pods of Sulawesi 01. According to the assessment criteria yield losses (Y) was calculated based on Wardani *et al.* (1997) as bellow:

$$Y = -0.0210 + 0.1005 I$$

Y is yield losses, I is the score of intensity damage due to CPB.

$$I = [(0 \times \text{pods number with healthy category}) + (1 \times \text{pods number with light damage category}) + (3 \times \text{pod number with moderate damage category}) + (9 \times \text{pods number with heavy damage category})] / (\text{number of observed pods}).$$

The resistance was classified according to the yield losses with criteria of resistant (0–20%), moderate resistant (>20–40%), moderate susceptible (>40–60%), susceptible (>60–80%) and highly susceptible (>80%).

PPR incidence was calculated based on number of infected pod due to Phytophthora infection per tree during the evaluation time. Intensity of PPR incidence is the proportion of infected pods divided by total observed pod then be classified as resistant (0–20%), moderate resistant (>20–40%), moderate susceptible (>40–60%), susceptible (>60–80%) and highly susceptible (>80%).

To confirm the field resistance, the detached pods of the tested clones were also tested by using artificial inoculation method at the Laboratory of Phytopathology of ICCRI refer to the method reported by Susilo & Anita-Sari (2014). For this test, the standard clones for resistance (Sca 6 and ICCRI 03) and susceptible (TSH 858) were also tested. The resistance was evaluated based on lesion size due to *P. palmivora* infection during 7 days after inoculation.

Damage severity due to VSD infection was measured using score system in the scale of 0–6 according to Susilo & Anita-Sari (2011). Evaluation was carried out during dry season (August–September 2013). Based on mean score the plants were classified for their resistance with category of resistant (0– \leq 2), moderate resistant (>2– \leq 3), moderate susceptible (>3– \leq 4), susceptible (>4– \leq 5) and highly susceptible (>5).

Variance analysis was subjected to yield data (kg/tree) then followed by stability analysis according to Eberhart & Russel (1966). Data for this analysis was collected from the sampled farm as replications. Due to the limitation of sampled farms for representing clone type, plant age and three replications, data were collected from the farm in the year of planting in 2008–2010.

RESULT AND DISCUSSION

Analysis of variance for yield indicated that there was no significant difference in yield between the tested clones (Table 2). This result confirmed that yield of locally selected clones of MCC 01 and MCC 02 was not significantly different with Sulawesi 01 as control. However, the yield potency of MCC 01 and MCC 02 was higher than Sulawesi 01 which means that the two clones would provide more benefit impact. That potency was also higher than ICCRI 03 and

ICCRI 04 both of which were previously released as the resistant clones to Phytophthora pod rot (Suhendi *et al.*, 2005). There were also no significant effect of plant age and no interaction between plant age and clone on yield performance which will be more influenced by genetic factor than by plant age or their interaction. Susilo (2011) reported that yield performance of cocoa hybrids was influenced by genetic factor also by altitude and climatic condition of the locations.

Stability parameters regarding deviation of regression of MCC 01 and MCC 02 were not significantly deviated to zero (Table 3) that enable to be interpreted that clone response to growth stage was linear. This result indicated that yield performance was stable during the stage of plant growth. Referring to the coefficient of regression it can be interpreted that the locally selected clones had general adaptability as the coeffi-

cient was not different to zero in contrast to Sulawesi 01 clone which was significantly different to zero (<1) that would be more adaptive to less favorable condition. In fact Sulawesi 01 clone grow well during all stages of growth in the so various agroclimatic conditions which indicating better adaptability in the less favorable environment. This results confirm that stability performance of the locally selected clones in term of growth stage showed the high potency of yield of those clones are stable expressed during all stage of plant growth.

Figure 1 and 2 show the high yielding performance of MCC 01 and MCC 02 in the field of North Luwu District area both of which are easily differentiated each other, especially with color performance of pod and flush. Those clones have been registered as local variety authorized by North Luwu District Government with register number of No.54/PVL/2013 and

Table 2. Variance analysis on the effect of cocoa clones and plant age to yield performance evaluated in farms in North Luwu, South Sulawesi

Sources of variation	Degree of freedom	Sum square	Mean of sum square	F _{test}
Total	8	20.72		
Clone	2	2.44	1.22	4.49 ^{ns}
Plant age + (clone x plant age)	6	2.75		
Plant age (linear)	1	1.75		
Clone x plant age (linear)	2	0.17	0.35	0.32 ^{ns}
Pooled deviation	3	0.82	1.09	
- MCC 01	1	0.09	0.09	0.76 ^{ns}
- MCC 02	1	0.54	0.54	0.13 ^{ns}
- Sulawesi 01	1	0.19	0.19	0.27 ^{ns}
Pooled error	26	18.29	0.70	

Note: (*) significantly different, (ns) not significantly different based on Fisher test at $\alpha = 5\%$

Table 3. Yield potency and stability parameters according to Eberhart&Russel (1966) observed in North Luwu (year of 2013 - 2014)

Clone	Yield (kg/ha/yr)	Comparing to Sulawesi 01 (%)	Regression coefficient (b _i)	Regression deviation (S ² _{di})	Stability
MCC 01	3,672.1	132.5	1.28 ^{ns}	-0.61 ^{ns}	Stable
MCC 02	3,132.2	113.0	1.17 ^{ns}	-0.17 ^{ns}	Stable
Sulawesi 01	2,772.3		0.57 [*]	-0.51 ^{ns}	Unstable

Note : (*)significantly different, (ns) not significantly different based on Fisher test at $\alpha = 5\%$



Figure 1. Performance of MCC 01 in the field indicating a high potency of yield



Figure 2. Performance of MCC 02 in the field indicating a high potency of yield

No.55/PVL/2013 (Susilo, 2013). The agronomic characteristics of these clones performed more vigorous habitus with semi erect branches so the plants are easily managed, especially on pruning treatment. Some farmers also informed the clones were easy to be propagated vegetatively using top grafting or side grafting method explaining why farmers prefer developing those clones. A few clones selected in North Luwu showed phenomena of grafting incompatibility e.g. Phanter clone but MCC 01 and MCC 02 did not perform grafting incompatibility. Scion of these clones are easy grafted on to the rootstock of hybrid seedlings. Goenaga *et al.* (2015) reported that the propagation methods of cocoa clonal material did not affect on the variable of pod number in which genetic effect should be more considered.

Yield stability evaluation in term of harvest time was carried out during all the year of assessment period. This information is very

important to evaluate the locally selected clones of MCC 01 and MCC 02 would be classified as continuously bearing pods or not (biannual behavior). Phillips-Mora *et al.* (2013) characterized some of cocoa collection at CATIE which perform biannual behavior of the production as was also performed by fine-cocoa clones in East Java. In case of smallholder farming, the biannual behavior of production is not suitable on supporting the sustainability of farmers income all the year. In fact, cocoa was mostly preferred by smallholder farmers due to the continuously production during all the year that significantly contribute to farmers income. The results indicated that locally selected clones of MCC 01 and MCC 02 continuously bear pods all months of the year of evaluation period with peak season of harvest in May-August (Figure 3). The behavior of continuous bearing pods is very useful to support the sustainability of farmers earn whose income mainly depend on cocoa.

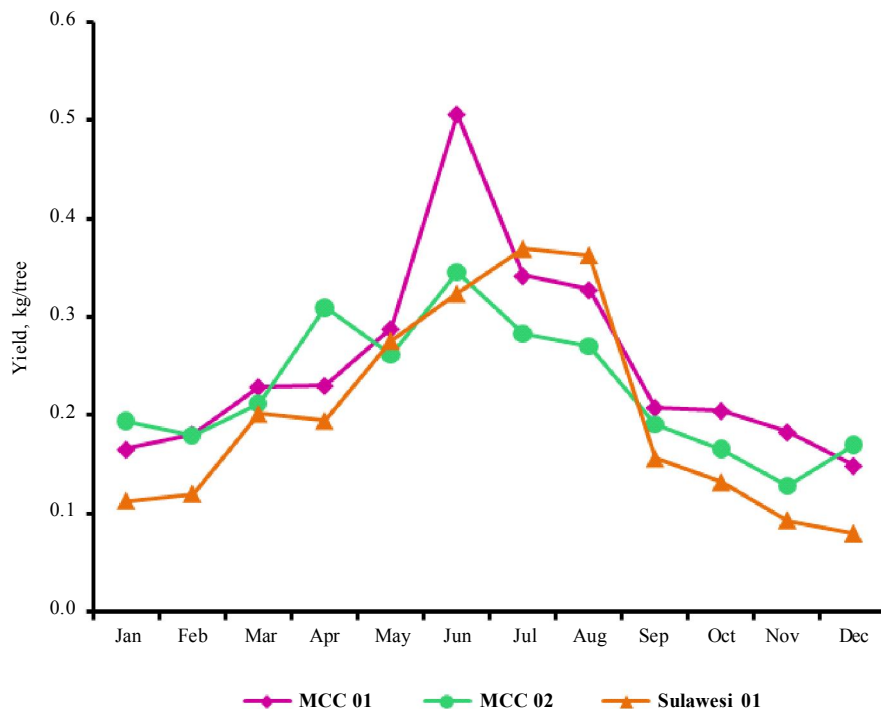


Figure 3. Monthly distribution of yield the locally observed cocoa clones in North Luwu (April 2013–April 2014).

Pest and diseases resistance

Field evaluation on CPB, VSD and PPR resistance indicated that MCC 01 and MCC 02 clones had good resistance to main pest/diseases (Table 4). Based on the data of yield losses due to CPB infection, it is shown that MCC 02 had the best resistance to CPB (yield losses 3.94%) while MCC 01 had moderately resistance to CPB (yield losses 20.96%). Comparing to the data from the previous studies indicate the yield losses due to CPB of the susceptible clones reached up to 66% (Susilo *et al.*, 2008) and >80% Wiryadiputra *et al.* (1994) that confirm the

two clones had better resistance to CPB. Factually in field, farmer's preference to MCC 02 was due to its resistance to CPB better than Sulawesi 01.

According to plant damage score due to VSD infections indicated that MCC 01 and MCC 02 had similar resistance to Sulawesi 01 with score less than 2.0. In an endemic area of VSD, susceptible trees would be very difficult to stand for live and producing pods. Susilo & Anita-Sari (2011) reported that the intensity of died plants in susceptible hybrids reached up to >50%. The preference of cocoa farmers

Table 4. Severity damage intensity due to field infection of CPB, VSD and PPR of MCC 01 and MCC 02 clones assessed in Nort Luwu District area

Clone	Yield lossess due to CPB, %	Mean score of VSD damage	Intensity of Phytophthora pod rot, %
MCC 01	20.96	1.12 ± 0.79	1.15 ± 0.56
MCC 02	3.94	0.71 ± 0.54	1.08 ± 0.55
Sulawesi 01	9.29	0.77 ± 0.52	2.58 ± 2.91

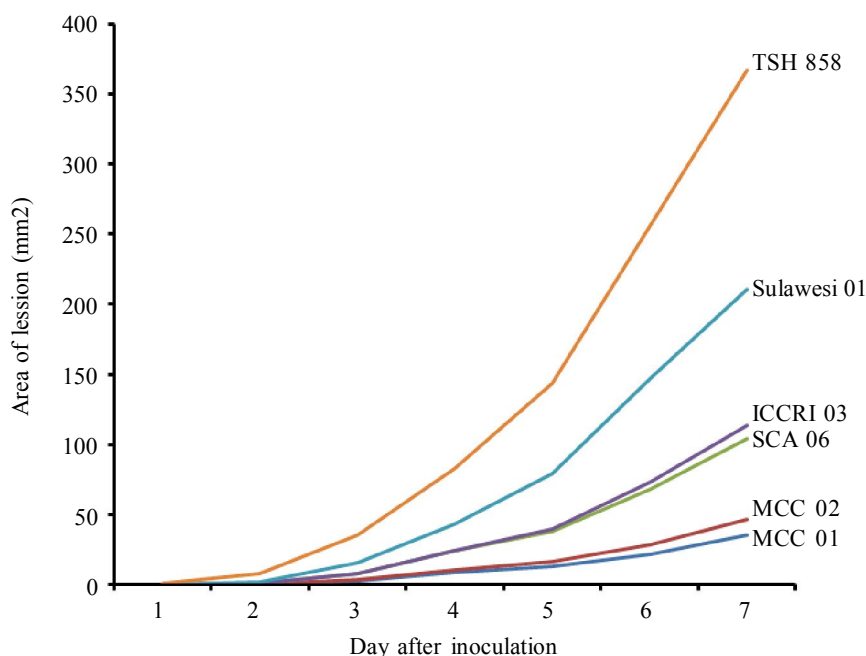


Figure 4. Development of lesion size during first 7 days after inoculation of *P. palmivora* between MCC 01 and MCC 02 with others tested clones with different level on PPR resistance.

for developing MCC 01 and MCC 02 as clonal material was due to their resistance to VSD.

Intensity of PPR incidence on the locally selected clones was about 1% which indicated that those clones had good resistance to *P. palmivora*. This result was in parallel with the laboratory test in which MCC 01 and MCC 02 showed resistance to *P. palmivora* with the lesion size was less than the resistant clones of Sca 6 and ICCRI 03 (Figure 4). The present result indicated that no significant difference between MCC 01 and MCC 02 clones and resistant clones of Sca 6 and ICCRI 03 and significantly different with TSH 858 the susceptible one. According to this results it could be concluded that MCC 01 and MCC 02 clones had good resistance to *P. palmivora*.

Bean quality

Table 5 shows the potency of bean quality of the locally selected clones compared to Sulawesi 01. The data indicated that the locally selected clones performed bigger size of dry beans than Sulawesi 01 which fulfill the AA classification according SNI (Indonesian standard for cocoa bean quality). This of bean size potency was similar to that of ICS 60 and UIT 1 which had bean size potency of 1.67 and 1.64 g per dry bean respectively which is the standard for big size of cocoa bean (Iswanto *et al.*, 2001). However, the potency of fat content are low, namely less than 50%, meanwhile up to now cocoa grinders still accept this quality regarding the fat content as Sulawesi 01 was used. This results had high potency for larger bean size than previous recommended clones of

Table 5. Yield component of MCC 01, MCC 02, and Sulawesi 01 observed in North Luwu

Clone	Dry weight bean (g) ^b	Shell content, %	Nib fat content (%)	Bean number per pod	Pod index
MCC 01	1.61 ± 0.36	15.9 ± 2.16	49.67	38.3 ± 5.17	14.3
MCC 02	1.75 ± 0.43	12.0 ± 1.62	49.20	42.8 ± 8.71	14.7
Sulawesi 01	1.10 ± 0.16	17.7 ± 2.87	47.80	40.3 ± 8.98	23.6

Note^b: Classified according to Indonesian National Standard (SNI), namely AA (maximum 85 beans per 100 g) or 1.17 g per dry bean, A (86–100 beans per 100 g) or 1.16–1.0 g per dry bean, B (101–110 beans per 100 g) or 0.99–0.90 g per dry bean, C (111–120 beans per 100 g) or 0.90–0.83 g per dry bean, and S (>120 beans per 100 g) or <0.83 g per dry bean.



Figure 5. Nib size of MCC 01, MCC 02 and Sulawesi 01

Sulawesi 01.

Referring to their high potency of yield, resistance to pest and diseases and bean quality, the locally selected clones of MCC 01 and MCC 02 were released as the recommended planting materials based on degree of Ministry of Agriculture No.1083/Kpts/SR.120/10/2014 and No.1082/Kpts/ SR.120/10/2014, respectively (Susilo, 2015). Those clones can be developed in monoclonal system due to both of which are self compatible, however it is recommended to plant in polyclonal system especially planted with others recommended clones such as Sulawesi 01 and Sulawesi 02 to increase horizontal resistance. MCC 01 and MCC 02 clones have to be propagated vegetatively by using top grafting method, budding or in vitro culture using somatic embryogenesis methods. Those clones are suitable planted in the area with agro-climatic condition similar to North Luwu District area. The plant variety which were participatory selected have a specific adaptation to agroclimatic condition refer to the local environment in where it was developed (Ceccarelli & Grando, 2007).

CONCLUSION

The observation of yield performance of the locally selected clones in North Luwu District indicate that clones of MCC 01 and MCC 02 have yield potency of 3,682 kg/ha/yr and 3,132 kg/ha/yr, respectively, higher than Sulawesi 01 of 2.772 kg/ha/yr. Performances of the yield are stable along the plant age. Field resistance evaluation indicate that MCC 01 performs moderate resistance to CPB, resistance to VSD and resistance to Phtytophthora pod rot, while MCC 02 performs resistant to CPB, resistance to VSD and resistance to Phtytophthora pod rot. The bean size of MCC 01 and MCC 02 are 1.75 and 1.60 g/dry bean, respectively, which fulfill AA qualification according to SNI.

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