Increasing productivity of mungbean \textit{(vigna radiata} (L.) Wilczek\textit{)} under subsistence farming in Eastern Indonesia

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Abstract. Mungbean is one of the major food legume and cash crops grown and consumed by small holder farmers under rain-fed conditions in Eastern Indonesia. However, the mungbean productivity has been low, less than 1 ton ha\textsuperscript{-1} due to a number of reasons including poor awareness about new varieties and skills of crop management. Two trials: varietal trial and management practices were conducted at Malaka District, East Nusa Tenggara during wet season 2008. The varietal trial in six sites resulted in identification of Sriti, Murai, Betet, and Vima 1 varieties had high productivity (1.1-1.5 t ha\textsuperscript{-1}) with single harvest, shorter maturity, compared to the local varieties which were characterized by lower productivity (1.0-1.1 t ha\textsuperscript{-1}), multiple harvests and longer maturity. The management practices found that selected varieties in combination with improved technology gave doubled seed yields compared to the yields when grown using local technology. These activities showed a reliable pathway to increase productivity of mungbean at small holder levels. The varietal and agronomic management trials demonstrated the impact of the technologies on mungbean productivity at small holder levels and identified future needs to sustain food productivity in remote regions on Eastern Indonesia.

1. Introduction

Based on the nutritional point of view, mungbean \textit{(Vigna radiata} (L.) Wilczek\textit{)} grain is rich in protein, carbohydrate, minerals (especially potassium, phosphorus), micronutrients (especially iron and zinc), and amino acids especially glutamic, cysteic and aspartic acids, leucine and lysine [1]. The grains had been used as complementary of the mainly-starch based diets (obtain from cereals and tubers) of people in developing countries. Moreover, the presence of significant amount of bioactive compounds make mungbean grains as popular functional food that promote a good health [2]. Mungbean grains are consumed worldwide especially by most people in Asian countries, and both for food and feed in smallholder farmers in developing countries.
Mungbean is a short duration legume that fits well as a component of cropping pattern in dry areas with short rainy season and prolonged dry season, because of its superior characters viz. short duration, low input, minimum care requirement, drought tolerant. The mungbean crop is widely cultivated both commercially in America, Australia, China, and traditionally in South and South East Asia, in arid and semi-arid areas of East Africa such as in Tanzania, Kenya, and Uganda, as well as the important pulse crop in Thailand, the Philippines, Sri Lanka, India, Birma, Bangladesh, and Indonesia [3-6].

Mungbean is very popular among small holder farmers under rain-fed conditions in Eastern Indonesia especially in East Nusa Tenggara Province (ENT). In this province, mungbean, maize, sorghum, peanut, and cassava are grown under small scale subsistence farming. Maize, sorghum and cassava are grown with the main priority is to fulfil the daily consumption of farmers’ households. In this ENT society, mungbean serve three functions i.e. as source of cash, staple food, and social purposes by 74.5%, 15.7%, and 9.8%, respectively [7]. The role of mungbean as grower’s household consumption was also present both in semi-subsistence and commercial farmers [8]. In ENT predominantly in Malaka (formerly Belu) District, West Timor as many as 23,000 hectares of mungbean crops is grown annually with average yield of 0.8 t ha$^{-1}$ of grains [9]. The popularity of mungbean among the ENT society has brought this province into the sixth rank of national mungbean producers in Indonesia. This regional productivity, however, was lower compared to its national productivity of 1.079 t ha$^{-1}$ in year 2019 and even higher by 1.183 t ha$^{-1}$ in year 2015. The reduction in productivity and production also occur in many central production areas such as in Ponorogo District, East Java Province [10]. As a matter of fact, the national productivity of mungbean was gradually decline in the last five year (2015-2019). This similar reduction trend was also occurring on acreage: from 229,475 ha to 181,463 ha in the same period. The reduction of productivity and harvested areas resulted in reducing grains production from 271,463 tons in 2015 to 195,839 tons in 2019 [11]. Th e low productivity is because the presence a number of constraints such as limited access to improved varieties, poor seed quality, drought stress, poor or traditional cultural practices, pest attack and disease infection, weeds infestation, and lack of knowledge about improved cultural technologies [3][5,6,10].

A series of activities on mungbean farming in ENT under ACIAR project # 068: “Productivity and Profitability Enhancement of Tropical Pulses in Indonesia and Australia” has been introduced and ended up with increasing income of participating farmers where the profit up to 700 USD per hectare has been enjoyed by farmers [7]. This benefit was due to huge increase of grains production that enabling participating farmers to sell more grains. All these achievements were obtained by the presence of scenarios to invite several parties i.e. research institutes who bring new improved varieties and guide farmers to improve their cultural practices, and local commercial bank to provide low-rate credit scheme to farmers who willing to improve their cultural practices. Access to credit was reported by [5] as an important component for adoption of new agronomy technology especially for components of chemical fertilizers, row planting, seed treatment with fungicide, and pesticide application. Further, access to credit was closely associated with the success of improved production technology adopted by farmers both in mungbean [5] and rice [12]. Also [13] reported that varietal and agronomic management were the main reasons for low mungbean yield in Bangladesh, and improving the cultural practices was done by introducing: new varieties, recommended plant spacing, inorganic fertilizer dosage, land preparation, and pest control. It has been realised that low mungbean productivity of less than 1 ton ha$^{-1}$ at the farmer’s level in ENT was due to a range of reasons including poor awareness about new varieties and skills of crop management. Despite the local varieties have adapted to drought and existing farming system, these local varieties have low productivity, multiple harvests and longer maturity. Besides, no information is available on site specific technologies including improved varieties, cultural practices. The objective of the studies was to determine seed yields obtained from varietal and agronomic management trials demonstrating the impact of the technologies on mungbean productivity at small holder level.
2. Materials and Methods

2.1. Varietal Trial

The experiment was conducted in dryland at six farmer’s fields in Betun, Sub District of Central Malaka, the District of Malaka, West Timor, ENT during wet season from June to August 2008. Four Indonesia released varieties viz. Betet, Murai, Sriti and Vima 1 as well as Sampeong, Fore Belu and Local Kefa (as local checks) were used as treatments and arranged in a randomized complete block design with four replications in each site. Each varietal treatment was planted in 2 m × 5 m that was equal to 10 m$^2$ plot size with plant spacing of 40 cm between rows and 10 cm intra row, 2 plants hole$^{-1}$. Basal fertilizers of composite fertilizers (250 kg of composite NPK inorganic fertilizer ha$^{-1}$ with 15% N, 15% P, 15% K, and 15% S contents) was applied at planting time. Seeds were treated with captan fungicide just before planting to reduce fungal infection. The crops were grown under rain-fed condition. Observations on crop growth, yield components and seeds yield were obtained from all crops in the area of 2 m × 5 m (10 m$^2$). The observations during the growing season were: time to 50% flowering, time to 80% of mature pods. The observations at each harvesting time (harvesting 1 and harvesting 2) were: days to harvest, pod weight plot$^{-1}$, seed weight plot$^{-1}$. Plant population was calculated at the second harvesting time. Whilst the weight of 100 seeds was observed after the seeds had been bulked from both harvests. Dry seed yield obtained in each subplot was weighed then converted to yield ha$^{-1}$. Data were analysed using an analysis of variance, and was followed by LSD test when there were significant differences.

2.2. Management Trial

The trial was conducted during wet season from June to August 2008 at three sites in Betun, Sub District of Central Malaka, the District of Malaka. A split plot design with three replicates was applied in each location. The main plot was management practices: farmer’s (local) technology (P1) and improved technology (P2). The subplot was mungbean varieties: Vima 1 (V1), Murai (V2), and Sriti (V3). Each treatment combination (subplot treatment) was planted in 2 m × 5 m plot size. The details technology tested were listed in Table 1.

| Components of Technology | Local Technology | Improved Technology |
|--------------------------|------------------|---------------------|
| Soil tillage             | Total, minimum, or zero | Zero or no tillage |
| Sowing method            | Broadcasted, irregular plant spacing | Dibbled, regularly sown in rows with plant spacing of 40 cm x 15 cm |
| Variety                  | Local            | Improved varieties: Vima 1, Sriti, Murai |
| Seed source              | Uncertified seeds obtained from farmers/local markets | Certified seeds (obtained from Iletri and Regional Agricultural Office) |
| Population               | Low population  | 2 plant hole$^1$, approximately 333,333 plants ha$^{-1}$ |
| Weeding                  | Manual           | Pre-emergence herbicide (glyphosate) applied at planting time with concentration of 4-6 cc L$^{-1}$ |
| Fertilizer               | No fertilizer   | Inorganic fertilizer (two times application) |
| Pest Control             | No control      | Pesticide application |
| Harvesting               | 2-3 times       | 1 time |
| Harvesting method        | Manual          | Manual |

At harvest time, observations were made on plant population, seed yield, the number of pods per plant and seed/pod weight ratio. Dry seed yield obtained in each subplot was weighed then converted to yield ha$^{-1}$. 

Table 1. Description of farmer’s (local) technology and improved technology. The District of Malaka
3. Results and Discussion

3.1. Central Malaka climate conditions
The location of these experiments was the Betun area in Central Malaka Sub District, Belu Regency (currently Malaka Regency). This area is classified as a semi-arid area or dry area with a total of 7 to 8 wet months, from November to May or June. However, this is different from other areas in the island of Timor, where in other areas, after a wet month, it is immediately followed by dry conditions without any rainy day until November. Meanwhile, at the location of the study, rainfall continued until July with a decreasing amount. In taking advantage of this wet month, the local people take advantage of this condition by organizing two planting seasons. The first planting season lasts from December to March and the second planting season is from May/June to July/August. In the first growing season, farmers usually plant maize, cassava, peanut or sorghum, and maize and mungbean in the second season. It is recorded that the annual rainfall for the last 30 years is 1524 mm with details in the period November to June 1417 mm and July to October is 107 mm. Thus, this research area is classified as type D climate according to the Schmidt and Ferguson classification with 60.0 =< Q < 100.0. The second planting season has 189.2 to 328.6 mm of precipitation (Fig. 1). This amount of rainfall has been enough to support good mungbean growth and its seed yield, besides, 400-550 mm of rainfall that is well distributed during the growing period is is suitable for cultivate a long duration variety with 60 - 90 days to harvest [14].

![Figure 1. The average amount of rainfall within 30 years in Central Malaka District (15)](image)

3.2. Varietal Trial
The improved varieties of Vima 1, Sriti, and Murai obtained significantly higher seed yields than those of local varieties Betet, Sampeong, Fore Belu, and Local Kefa. Among those three improved varieties, Sriti gave the highest yield by 1,542 kg ha⁻¹. The average productivity of improved varieties ranged from 1,097 kg -1,542 kg ha⁻¹ and those of local varieties i.e. Sampeong, Fore Belu, and Local Kefa were from 1,042-1,285 kg ha⁻¹ (Table 2). It is clear that improved varieties, which were also modern varieties, had higher productivity than those of local varieties as also stated by [16]. Superior seed yield obtained by improved variety was obtained when the crops had an excellent growth so that reach a high leaf area (LA), total dry matter (TDM), and crop growth rate (CGR) and not due to superior pod and seed size [17]. Whilst [16] reported that total weight of dry matter per plant⁻¹ was affected by
number of branches per plant$^{-1}$ and plant height per plant$^{-1}$ where less number of branches and lower plant height related to less dry matter production.

Table 2. Mean, maximum and minimum seed yield of seven genotypes across six sites. The District of Malaka, wet season 2008

| Variety     | Seed yield (kg ha$^{-1}$) | Maximum | Minimum | Mean ± SD |
|-------------|----------------------------|---------|---------|-----------|
| Vima 1      | 2,092                      | 487     | 1,388 ab| 513       |
| Sriti       | 2,141                      | 804     | 1,542 a | 480       |
| Murai       | 1,855                      | 780     | 1,389 ab| 373       |
| Betet       | 1,438                      | 512     | 1,097 cd| 341       |
| Sampeong    | 1,768                      | 760     | 1,285 bc| 348       |
| Fore Belu   | 1,461                      | 606     | 1,042 d | 399       |
| Local Kefa  | 1,602                      | 725     | 1,150 cd| 261       |

Note: numbers in the same column followed by similar letters did not significantly different based on LSD test at $\alpha = 0.05$

The huge difference between maximum and minimum seed yield of each variety tested indicated the presence of different response of varieties to the growing areas. This statement was supported by the combined analysis of variance on seed yields that indicated the presence of genetic and environment interaction (analysis variance was not presented). It means that location affected yield performance of each variety. Sriti and Murai varieties were superior in five sites; while Vima 1 variety was superior in four sites only (Fig. 2). Figure 2 also tells that among six sites, mungbean grown in site 6 (Loc. 6) gave lowest seed productivity (668 kg ha$^{-1}$ of mean seed yield) and conversely for that in site 2 (Loc. 2) with 1,710 kg ha$^{-1}$, and the average seed productivity over six sites was 1,270 kg ha$^{-1}$. These varietal trials obtained higher mean seed yield than the average of seed yield from District Malaka (800 kg ha$^{-1}$), even it is higher than the national seed yield.

Figure 2. The seed yield of seven varieties grown in six sites. The District of Malaka, June-August 2008 growing season.

In all six locations, variety of Vima 1 was the earliest to main harvest (57.1 ± 3.6 days) similar to those of Sriti (57.7 ± 2.3 days), Murai (57.8 ± 2.1 days), and Betet (57.8 ± 2.1 days). These varieties were harvested two days earlier than that of Local Kefa (59.2 ± 3.1 days), while Sampeong and Fore Belu had latest maturity as they were harvested at 63 ± 2.5 days and 64.8 ± 2.6 days, respectively. The
second harvest, as the final pod picking to finish harvest, gave slightly different time: Vima 1, Betet had the earliest time, conversely Murai and Local Kefa had the latest harvesting time (Table 3). In other words, hand picking of pods were done at different dates as per maturity of different varieties.

### Table 3. Varietal characters contributing to yield difference (averaged from six sites). The District of Malaka, June-August 2008 growing season.

| Variety       | Days to first harvest (80% mature) | Days to finish harvest (days) | % no. pods at first harvest | % no. pods at second harvest | Weight of 100 seeds (g) | Pod dehiscence |
|---------------|------------------------------------|------------------------------|-----------------------------|------------------------------|-------------------------|----------------|
| Vima 1        | 57.1                               | 59.7 b                       | 94.7 a                      | 5.3 b                        | 5.88 c                  | indehiscence   |
| Sampeong      | 63.6                               | 70.8 a                       | 89.9 ab                     | 10.1 ab                      | 3.02 d                  | indehiscence   |
| Sriti         | 57.7                               | 69.1 ab                      | 93.1 a                      | 6.9 b                        | 6.53 b                  | indehiscence   |
| Murai         | 57.8                               | 73.3 a                       | 86.8 b                      | 13.2 a                       | 6.39 b                  | indehiscence   |
| Betet         | 57.8                               | 59.7 b                       | 93.1 a                      | 6.9 b                        | 5.95 c                  | indehiscence   |
| Fore Belu     | 64.8                               | 66.1 ab                      | 87.5 b                      | 12.5 a                       | 6.95 a                  | dehiscence     |
| Local Kefa    | 59.2                               | 74.0 a                       | 86.3 b                      | 13.7 a                       | 7.11 a                  | dehiscence     |

Note: Numbers in the same column followed by the same letters indicated not significantly different based on LSD test at $\alpha = 0.05$.

Another superior character for Vima 1, Sriti, and Betet varieties was that almost all pods (at least 93% of pods) were hand-picked at the first harvesting time and only small amount of pods left for the second harvest. On the other hand, Sampeong, Murai, Fore Belu, and Local Kefa showed the different figures (Table 3). Different harvesting time among pods was mainly because the pods did not ripe simultaneously. When farmers do mechanized mungbean practices, they do harvest in one go and therefore a simultaneous maturity time of pods is preferred.

The variation in 100-seed weight among those seven varieties might be due to their different genetic characteristics. Study conducted under kharif (summer) condition in Bangladesh used small seeded mungbean varieties with 3.023-3.597 g 100 seed$^{-1}$ [16], while [18] used the wide adaptability Ethiopian varieties obtained from their national Agricultural Research Center with 4.532 g and 5.695 g 100 seed$^{-1}$. All improved varieties had the indehiscence pods (Table 3). This means that the pods would not be crack/split when harvest is undertaken late. In summary, combining early maturity, simultaneous pod maturity, and high yield, as well as indehiscence characters belong to Vima 1 variety resulted that this variety represents an attractive component of agronomic package technology.

### 3.3. Management Practices

The response of improved varieties to management practices was also significant. Sriti, Vima 1, and Murai varieties gave higher seed yields when cultivated by improved technology (Table 4). Sriti variety performed better both in local and improved technology as shown by its highest seed yields. On the other hand, the performance Vima 1 was ultimately influenced by the management practices introduced, or Vima 1 was responsive to technology applied (Table 4).

Table 4 tells that management practices affected seed yield. Improved technology gave the mean yield of 1,232 kg ha$^{-1}$ that was 1.4 times higher than that obtained by local technology (865 kg ha$^{-1}$) when the improved or modern varieties were used as planting materials. In other words, the application of better management (through more inputs) in improved technology raised up the seed yield up to 42%, whereas [19] introduced the 40% increase. The seed yield was even worse when local variety was grown under local or farmers cultural practices, where the seed yield of local variety under farmer’s management was in the range of 0.28 to 0.70 t ha$^{-1}$, with 0.412 t ha$^{-1}$ in average obtained from the yield cut sampling from 25 local farmers.
Table 4. Seed yield of three mungbean varieties grown in two management practices. The District of Malaka, June-August 2008 growing season.

| Variety   | Improved Technology (kg ha\(^{-1}\)) | Local Technology (kg ha\(^{-1}\)) | Average variety (kg ha\(^{-1}\)) |
|-----------|--------------------------------------|----------------------------------|----------------------------------|
| Variety Vima 1 | 1,234                                | 750                              | 992                              |
| Variety Sriti   | 1,350                                | 1,016                            | 1,183                            |
| Variety Murai  | 1,112                                | 829                              | 971                              |
| Average yield (kg ha\(^{-1}\)) | 1,232                                | 865                              | 1,049                            |

Higher plant population at harvesting time, the number of pods plant\(^{-1}\) and seed/pod weight ratio were the main components for higher yields (Table 5). Several studies on mungbean and soybean showed that number of pods plant\(^{-1}\), number of seeds pod\(^{-1}\), weight of seeds plant\(^{-1}\), number of pod plant\(^{-1}\), seed size, significant and positively correlated to seed yield [20]; [21]; [22]. [23] reported that productivity of mungbean in Malaka District tended to reduce due to degradation of soil fertility as farmers hardly ever applied chemical fertilizer. An expensive chemical fertilizer as well as the locally unavailable was the main reasons. Application of organic fertilizers i.e., 10 t ha\(^{-1}\) of sawdust biochar mixed with 3 t ha\(^{-1}\) of cow manure increased soil moisture content, soil electrical conductivity, decreased soil temperature and bulk density, and later was successfully gave highest vegetative growth such as stem diameter, plant height, root length, total shoot and root dry weight.

It can be summarized by introducing more inputs such as chemical fertilizer, pesticide, herbicide, improved variety as components of Improved Technology Package, the yield increase was obtained. Unfortunately, farmers in dryland under subsistence farming really have limited source of cash and therefore they do not afford to buy those agricultural components for producing mungbean. In addition, that occupation and knowledge of farmers were positively and significantly correlated with adoption of mungbean production technology [24].

Table 5. Plant population at harvesting time, the number of pods per plant and seed/pod weight ratio of mungbean grown in two management practices. The District of Malaka, June-August 2008 growing season.

| Yield Components          | Local (Farmer) Technology | Improved Technology |
|---------------------------|---------------------------|---------------------|
| Plant population ha\(^{-1}\) | 156,646 ± 89,574          | 294,213 ± 51,256    |
| No of pods plant\(^{-1}\)  | 12 ± 9.2                  | 33 ± 8.5            |
| Seed size (g 100 seeds\(^{-1}\)) | 6.3 ± 0.44               | 6.7 ± 0.52         |
| Seed/pod weight ratio (%)  | 71.9 ±12.8                | 76.5 ± 8.2          |

During three years period of the project, farmer’s field days held in central production areas gave a significant effect to the development of Vima 1 variety together with the promising improved management practices. As a result, farmers and stakeholders got interested in developing Vima 1 in their fields. Recently, Vima 1 variety and the improved technology have been developed and adopted by most mungbean farmers in central production areas in West Timor, Sabu, Flores, Sumba Islands in East Nusa Tenggara Province.

4. Conclusion

Based on the results of the research, it can be concluded that the multi-location evaluation resulted in identification of varieties with high productivity with single harvest, shorter maturity, compared to local varieties. The selected varieties in combination with introduced inputs showed a reliable pathway to increase productivity of mungbean at small holder level. Among the improved varieties, Vima 1 variety is now widely grown by farmers in main islands of East Nusa Tenggara.
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