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Grain Yield of Rice, Corn, and Sorghum to Low External Input Agriculture Practices in Maliana, Bobonaro, Timor Leste

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Abstract

A farmers' field yield trial during the 2018 dry season was conducted in Maliana, Bobonaro District, Timor Leste to evaluate the compatibility of selected hybrid and inbred varieties of rice, maize, and sorghum to low external input crop management practices common to subsistence farmers in the region. In rice, grain yield performance as influenced by genotype (hybrid or inbred) and planting density (single or double row spacing) was assessed by measuring grain yield and selected agronomic traits. In rice, grain yield was not significantly different, between hybrid and inbred varieties, but higher planting densities gave 17-27% advantage for hybrids and 36-45% for inbred varieties. The observed yield from farmers' field was, however, 60-70% lower than yield obtained from experimental fields. Agronomic traits (plant height, tiller, panicle, and spikelet counts) were found to have very strong genotype x planting density interaction effects, and although post-hoc analyses revealed marginal differences on selected yield-related components between the two planting densities, these differences were not statistically significant, and did not contribute to improvement in rice grain yield. Hybrid and inbred varieties of maize and sorghum showed comparable yield levels in two independent yield trials, and although agronomic traits showed significant differences between varieties, these did not account for any yield advantage.

***Keywords*:** Grain Yield; Rice; Corn; Sorghum; External Input; Agriculture Practices.

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1. Introduction

Rice and maize are the preferred cereal crops by many Timorese. During the Indonesian Occupation eastern territory of Timor—which only ended in the early 2000s—Maliana, in Bobonaro District, became a rice barn town. It supported other districts in East Timor, while also assisting in the rice exportation to Western Timor of Indonesia (Lopes and Nesbitt, 2012). This has since established Maliana's foothold in the crop production scene of Timor-Leste. In Maliana alone, land area dedicated to rice production stretches up to 1,244.7 ha (52%), followed by maize with 895 ha (33%) [2]. The remaining 15% are distributed for other crops.

Productivity from rice and maize is at 3.78 t/ha^{-1} and 1.4 t/ha^{-1}, respectively (TL Statistics, 2017). Rice yields are generally low from 1.8–2.5 t/ha and they differ with production methods. In areas with assured water during cropping season, yields of around 2.8 t/ha is considered attainable. This can be further increased to as high as 3.8 t/ha if only fertilizers and improved varieties of seeds are applied [1]. However, the application of these agricultural inputs is very limited due to high market prices, product shortage, and the skeptic attitude of farmers in using fertilizers. Only the subdistricts of Atabae, Cailaco, and, to some extent, Balibo, are among the agricultural lands where fertilizers are applied.

Similar to the situation on rice productivity, overall maize production is also constrained by low application of inputs, especially fertilizers and highly viable seeds. Other yield-enhancing technologies, such as mulching and nitrogen-fixing legumes are present but rarely practiced. Maize yield is generally low at around 1.2 to 1.8 t/ha. In times of drought and water stress, this figure is eventually reduced down to 1.0 t/ha or lower .

Planting density as a function of plant spacing and variety influence yield and selected agronomic traits, although this relationship varies by crop management technique. For instance, while grain yield of elite hybrid rice is expected to outperform that of elite inbred lines, but under dense planting and reduced nitrogen, inbred varieties outperformed hybrid rice varieties (Lu and his colleagues 2020) [3]. Inbred varieties, at least those included in the study.

Field trials on rice, maize and sorghum were conducted for one cropping season from June to December 2018 in Maliana, Bobonaro District, Timor-Leste. Lowland rice was planted in June and harvested in September 2018, while maize and sorghum field trials were carried out from June to December 2018. The crops were established and managed using common management practices of Maliana farmers. Due to financial and time constraints, the study only focused on Maliana, hence, the results of the field trial experiments and survey are only limited to a single subdistrict in Timor-Leste and may not apply to other crop growing areas in the country.

Objectives

The objectives of estudy are to:

• Evaluate the compatibility of selected hybrid and inbred varieties of rice, maize, and sorghum to low external input crop management practices common to subsistence farmers in the region.

• Evaluate on-farm performance of different varieties of rice, maize and sorghum in Maliana, Bobonaro District, East Timor.

• Evaluate the productivity, profitability and energy efficiency of rice, maize and sorghum production in Maliana, Bobonaro District, East Timor.

2. Materials and methods

2.1. Site description

Field experiments was conducted in Maliana, Bobonaro, Timor-Leste. The field trial was conducted during the dry season from June to December 2018 at the [altitude; longitude and latitude]. Hybrid and inbred rice varieties were planted in June and harvested in September 2018 while the combined corn and sorghum trial was conducted in June to December 2018. The crops were established and managed using the common management practices of Maliana farmers.

2.2. Soil fertility and physical properties

Soil samples were obtained for routine laboratory analysis, before land preparation. Soil physical and chemical properties such as: bulk density, porosity, soil water holding capacity (SWHC), organic matter, soil organic carbon, pH, CEC, Nitrogen, phosphorus, potassium, magnesium, and calcium were analyzed at laboratory of soil at Udayana University of Denpasar, Indonesia.

2.3. Crop establishment and maintenance

Seedlings were prepared through wet bed method. Sowing rate was 4000 seeds per square meter (m^2). Before seeding, seeds were soaked overnight (24 hours) and incubated for another 24 hours. Seedlings were transplanted 18 days after sowing. Transplanting was done in two spacings: 1) Square planting 25 x 25 cm, and 2) double row planting 25 x 12.5 cm with 50 cm interval before the next double row. Planting commenced in June 22 and harvest on September 29, 2018.

The treatments were two genotypes (hybrid and inbred) each of maize and sorghum, and double row plant spacings. Other than these treatments, all other crop-specific were employed across treatments i.e., land preparation, levels of input application and crop care and management were similar to common farming practices of Maliana farmers.

2.4. Experimental treatment and design

The treatments were two genotypes (hybrid and inbred) of rice, and two plant spacings (single and double row). Other than these treatments, all other recommended practices including fertilization and irrigation were similarly employed across treatments.

The experiment was laid out in a Randomized Completely Block Design (RCBD) with three replications. Plot size, sampling area for each crop and the total area for the field experiment are 884m^2 for rice, 36m^2 for corn and 36m^2 sorghum.

2.5. Grain yield and selected yield component measurements

The treatments were two genotypes (hybrid and inbred) each of corn and sorghum and double row plant spacings. Other than these treatments, all other crop-specific were employed across treatments i.e., land preparation, levels of input application and crop care and management were similar to common farming practices of Maliana farmers.

3. Results and discussion

3.1. Rice Field Trial

3.1.1. Yield

A two-way ANOVA did not detect any interaction between spacing and variety (p=0.460) on yield. Main effects of spacing (p=0.0853) was significant at an α=0.10 using LSD, but variety (p=0.710) was not. Overall yield was 27.12 kg 100 m^{-2}. Indeed, while the hybrids selected for this study had higher expected yield compared with inbred, they failed to achieve the threshold yield of 6.19-6.27 t ha-1 and fell short by 21-31%. Meanwhile, the inbred varieties recorded 109 44-65% more grain yields above baseline. Nona Porto, an inbred variety, achieved a yield of 6.3 t ha-1 or more than twice its expected yield of 3.19 t ha-1. Physiological causes that lead to inadequate grain filling have been proposed. In the present study, lower grain filling was likely a consequence of reduced solar radiation.

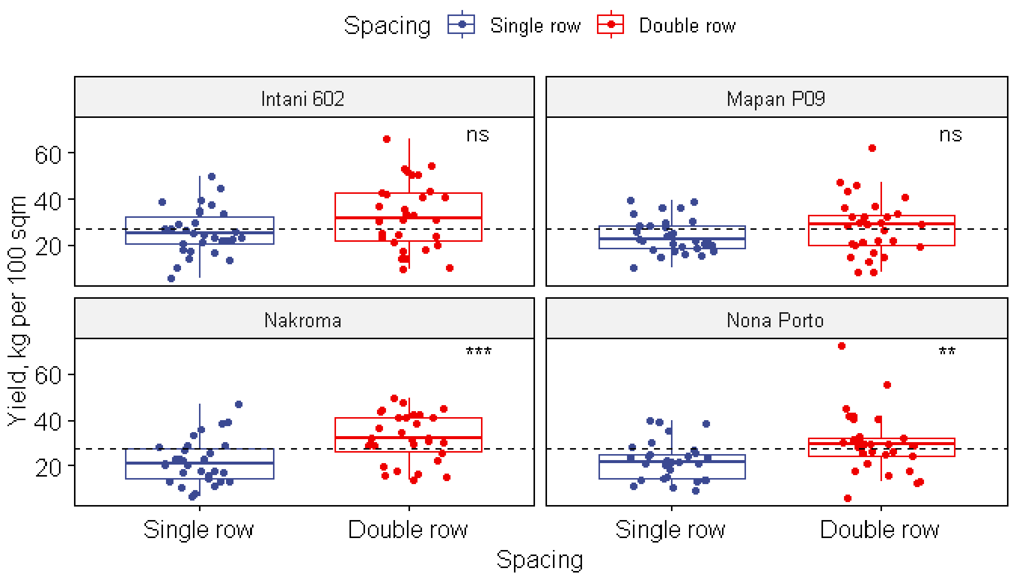

Figure 1: Grain yield (100 kg m^{-2}) in four rice varieties planted in either single row (SR) or double row (DR) spacing. Two-way ANOVA did not detect significant spacing x variety interaction but yield differences in inbred varieties planted in higher planting densities were found to be significant at an α=0.10 using LSD. Baseline yield was 27 kg 100 m^{-2}.

The rice crop was cultivated around July to September which is also when air temperatures are lowest in Maliana, indicating that while heat stress was unlikely, the relatively cooler temperatures also suggest a reduction in light availability that in turn slows down crop growth. It is known that yield potential of a rice crop is mainly dictated by intercepted light, particularly 3at the r3.2. reproductive stage [4]. For instance, 'Koshihikari' (Japonica) constrained by low light conditions during the ripening stage produced grains that had lower amylose content and decreased single-grain weight compared with grains from rice crop grown under more optimal light conditions (Ishimaru and his colleagues 2018).

3.1.2. Yield components

Highly significant spacing by variety interaction were detected for height (p=<0.001), tiller number (p=0.002), panicle number (p=0.026), and spikelet count (p=<0.001). To tease out group differences, post hoc analysis was performed on group means using LSD at α=5%.

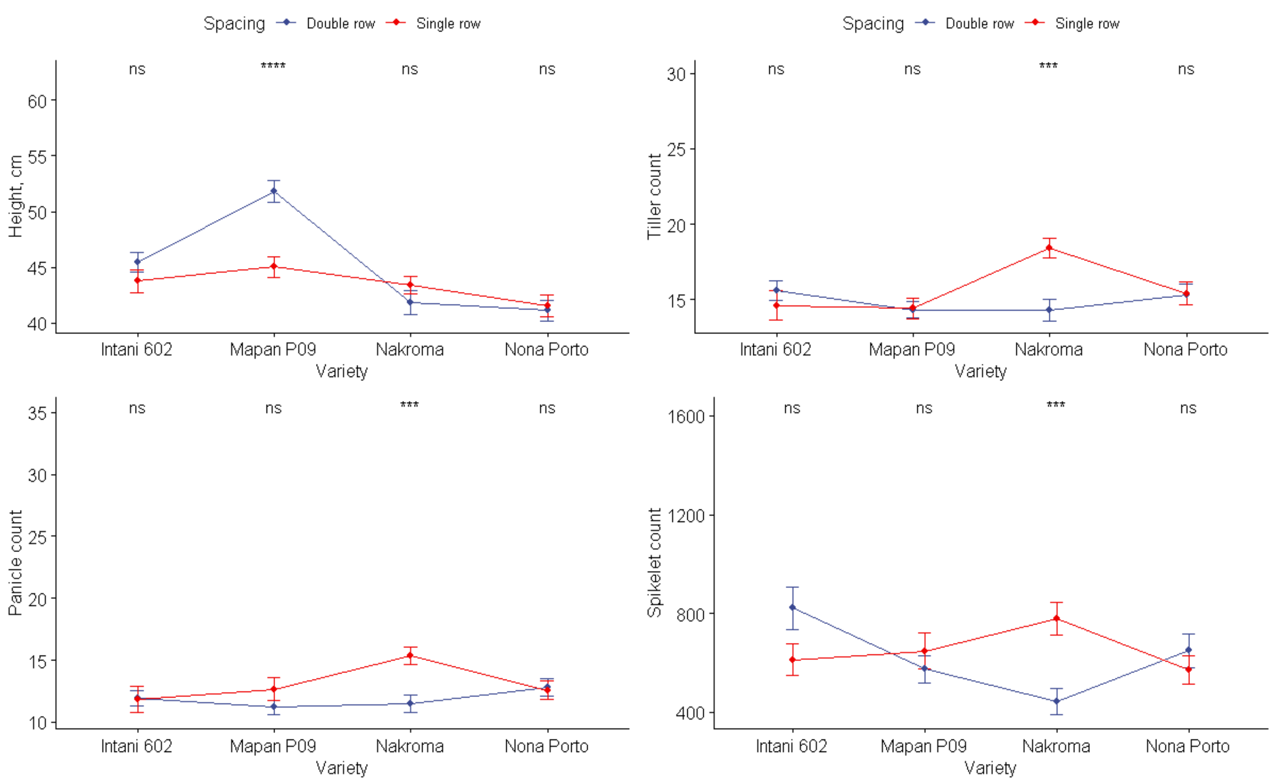

Figure 2: Highly significant interaction effects were detected for means of height (A, p=<0.0001), tiller count (B, p=0.002), panicle count (C, p=0.026), and spikelet count (D, p=<0.001) in four varieties of rice planted in either single row (SR) or double row (DR) did not vary, except for Nakroma which had significantly greater number of tillers, panicle and spikelet when planted in single rows. On the other hand, Mapan P09, a hybrid, was taller at higher planting densities (SR = 45 cm vs DR = 52 cm) but found to be 60-70% shorter when compared to its height of 92 cm in experimental fields. Data points represent n=3 and SEM. Post hoc group comparisons were performed using LSD at α=0.05.

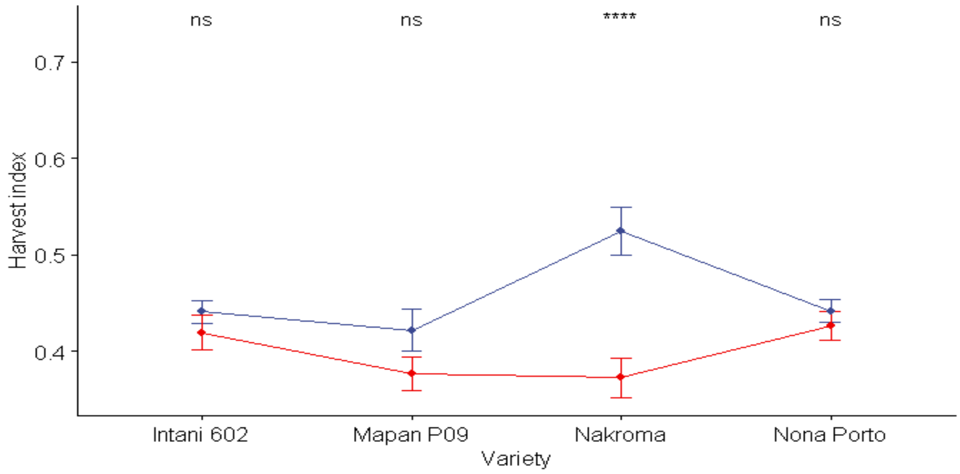

Figure 3: Harvest index.

Harvest index is a ratio between economic yield i.e., grain yield and total plant biomass. Nakroma, HI for Intani 602, Mapan P09 and Nona Porto were unaffected by row spacing. Nakroma, however, recorded an HI of 1.3 under DR and 65 for SR. The differences were statistically significant.

Further analyses revealed height difference in Mapan P09 was affected by row spacing (Figure xA). Mapan P09 has an average height of 95 cm, but at double row spacing it reached only a height of 52 cm and 45 cm when planted in single rows, which represent 60-70% reduction from its baseline height of 92 cm. The three other varieties were also shorter by 60-70% than their average reported height, although the height differences in a variety were not associated with row spacing. This difference is likely due to inter-canopy shading. The other genotypes were generally unaffected by row spacing in terms of plant height. A 20-25 cm increase in height was noted in all treatment combinations compared to reported baseline values. Planting density as a function of plant spacing and variety influence yield and selected agronomic traits, although this relationship varies by crop management technique. For instance, while grain yield of elite hybrid rice is expected to outperform that of elite inbred lines, under dense planting and reduced nitrogen, inbred varieties outperformed hybrid rice varieties (Lu and his colleagues 2020). Similarly, it could be argued that the inbred in the present study outperformed the hybrids by consistently producing yield higher than baseline [3].

On the other hand, highly significant differences in tiller (p=0.002), panicle (p=0.026), and spikelet (p=0.001) counts were influenced by row spacing in Nakroma. The hybrids Intani 602 and Mapan P09 and the inbred Nona Porto showed marginal differences in the same set of agronomic traits but their differences were not statistically different, suggesting that the observed values were influenced by other variables. higher planting densities provided the benefit of 25% greater grain yield across rice genotypes. The hybrids, Intani 602 and Mapan P09 and the inbred Nona Porto performed better under denser planting conditions, while Nakroma was more suitable in lower planting densities, which highlights the importance of determining the adequate population densities to avoid yield losses. Results of the yield components can partially explain these yield responses. Greater tillering and higher panicle counts translated to greater productivity under SR in Nakroma. Under DR, however, competitive relationships between and within plants in more populated row spacings resulted to lower total spikelet in this variety. On the other hand, row spacing did not influence the number of spikelets per panicle (SPP), which indicates that background plant genetics had more influence on SPP. SPP is an important agronomic trait that has a huge impact on grain yield. Commercial hybrid varieties such as Intani 602 and Mapan P09 are preferred because they show larger panicles (with more spikelet per panicle) (Yang and his colleagues 2012). These rice varieties tend to have larger sink sizes and therefore higher yield potential compared to inbred. Unfortunately, these hybrid varieties failed to reach the expected yield performance largely due to poor grain fill

3.2. Maize Field Trial

No statistically significant differences were found for plant height (p=0.1757; Fig.3) and yield (p=0.1569; Fig.14B). Cob length was found to be longer (p=0.001) in the hybrid variety, Bima-2, compared to the Sele, an inbred. The difference in cob length reflects the likely influence of the genetic background of maize hybrids having been selected.

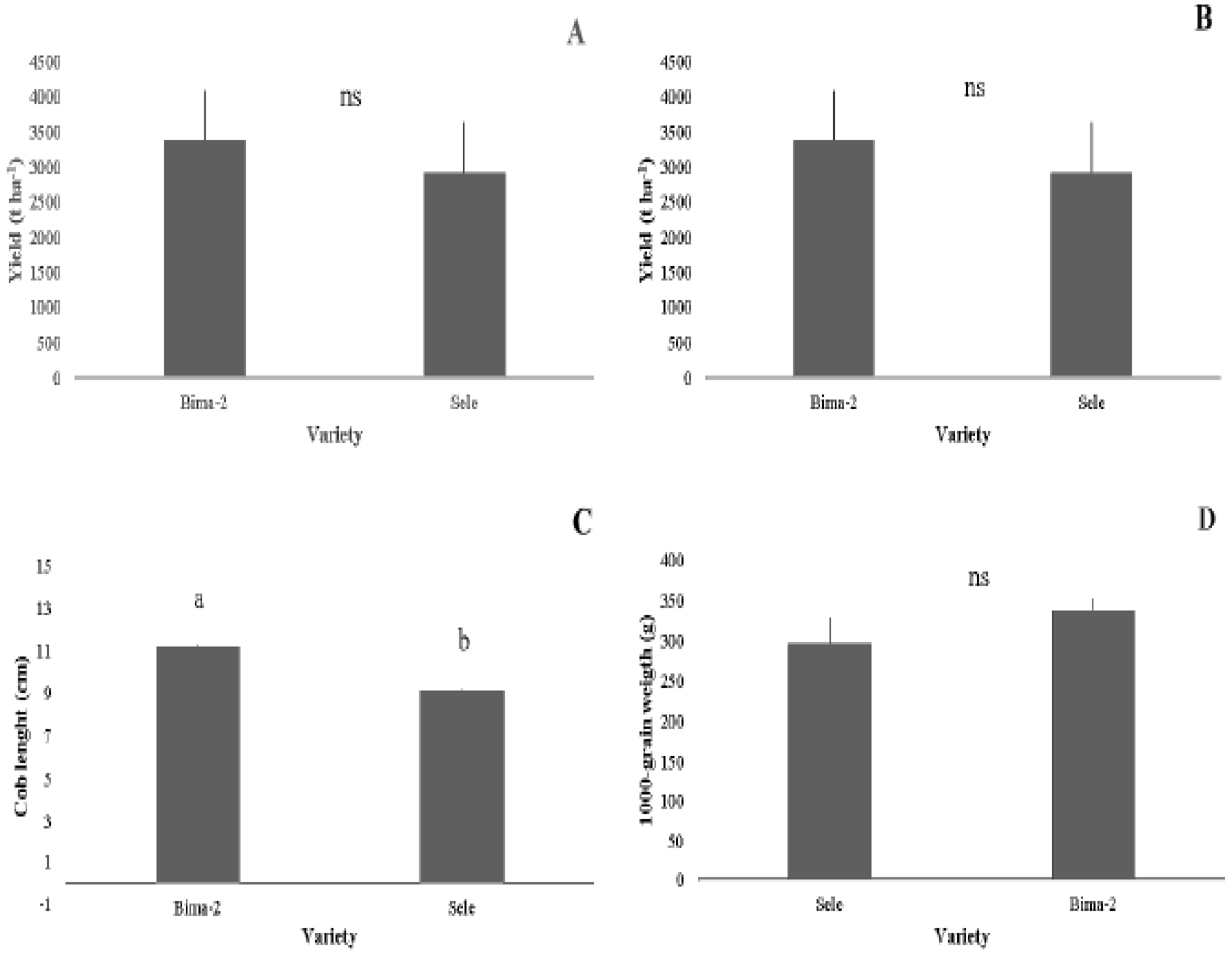

Figure 4: Selected agronomic traits collected for the maize adaptability trial. Plant height (p=0.1757) and yield (p=0.1569) were not significantly different between Bima-2 and Sele. Cob length was longer (p=0.001) in Bima-2 than Sele although 1000-grain weight (p=0.9876) were similar for both varieties.

However, plant heights were found to be shorter by 40-50% than expected (Figure 4). Also, neither variety performed well under experimental conditions in terms of grain yield (Figure xB). Yield obtained for the hybrid, Bima-2, was ca. 57% lower of the expected yield of 5.3-9.65 t ha-1. The results were the same for Sele, an inbred, which gave yields 47% less than the 1.54 t ha-1 baseline. 1000-grain weight was not significantly different (p=0.2985) between Bima-2 and Sele (Fig 14D). Likewise, harvest index (HI), was not significant (p=0.4591).

3.3. Sorghum Field Trial

A one-way ANOVA showed significant differences between inbred and hybrid for height (p=<0.001; Fig 15A) and 1000-grain weight (p=<0.01; Fig 15 C), but not for yield (p=0.2233 Fig 15B) and harvest index (p=0.1484; Fig 15D).

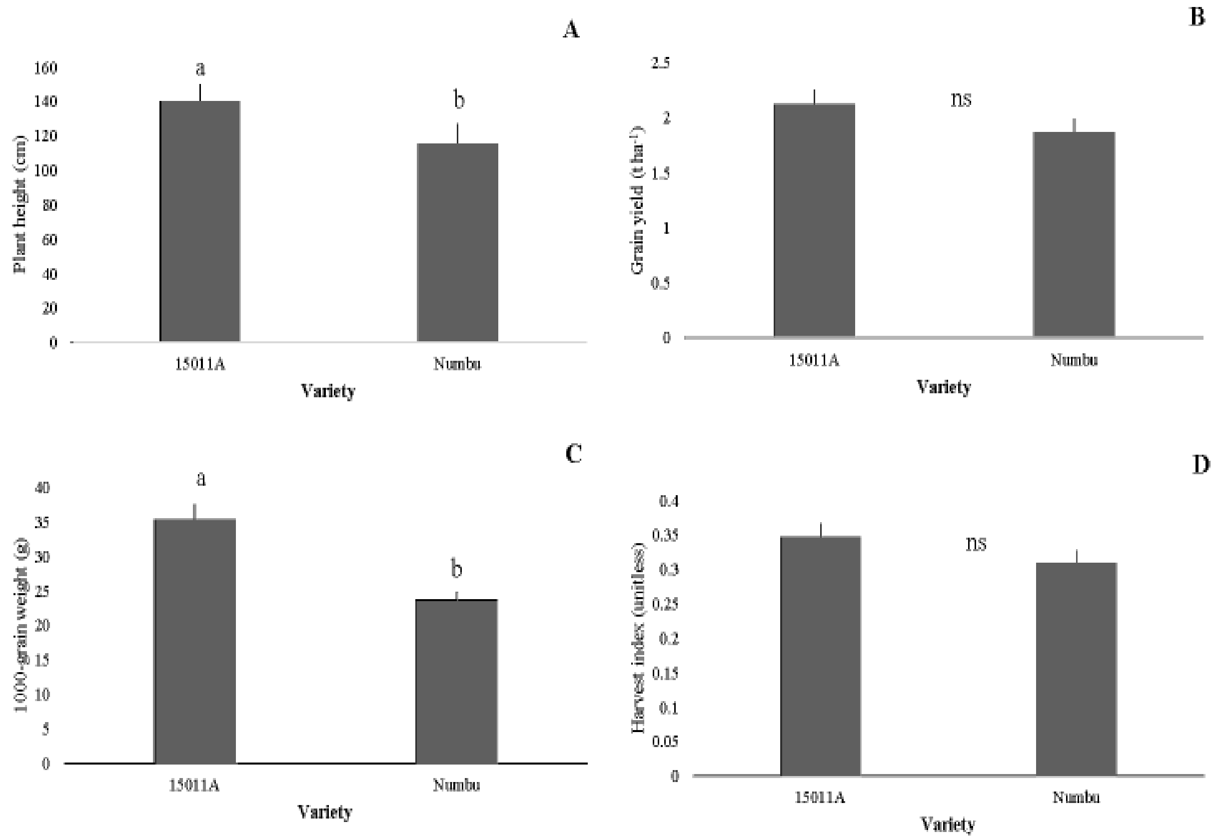

Figure 5: Selected agronomic traits collected for the sorghum adaptability trial. Plant height (p=<0.001) and 1000-grain weight (p=<0.01) were significantly different between varieties but yield (p=0.2233) and harvest index (p=0.1484) were not significantly were not. Bars represent the mean (n=3) and sem.

Plant height was significantly different (p=<0.001) between the hybrid 15011A (140.3 cm) and the inbred Numbu (116 cm) (Figure 15A). However, actual heights were 57-60% shorter than the expected baseline of 328 cm and 287 cm for 15011A and Numbu, respectively. Likewise, 1000-grain weight was significantly influenced by variety (p=<0.01). 15011A had higher 1000 -grain weight than Numbu (Figure 15B).

4. Conclusions and recommendations

4.1. Conclusions

The field experiments were conducted in Maliana, Timor-Leste to compare productivity, energy and resource use efficiencies of food caloric energy sources, rice corn and sorghum. For rice, row spacing and variety had no significant effect on plant height, and harvest index. Variety and row spacing did not significantly affect the number of tillers and yield components but there was significant interaction between variety and row spacing. Hybrid variety Intani 602 planted in double row spacing had the highest yield. The higher plant density increased the number of productive tillers, producing greater number of seeds. Hybrid varieties have genetically superior traits and higher yield potential. Plant height did not significantly vary between hybrid and OPV varieties of corn and sorghum. While variety significantly affected 1000 -grain weight with hybrid variety having heavier seeds than inbred variety, grain yield and harvest index of corn and sorghum did not significantly differ among varieties. The highest grain yield per ha for corn and sorghum while higher in hybrid variety of both crops, were still below the reported yields for these varieties. Better controlled field experiments is needed to better elucidate the yield gap constraints particular to the Maliana, and develop site specific recommendations. Hybrids planted in DR are more profitable compared with SR with net incomes of $1,492-1,672 and $1,877-2,798 per ha, respectively. Inbred yield and profitability depend on variety and planting density, but all combinations are also profitable.

4.2. Recommendations

Farm trial conducted was unable to demonstrate conclusively the expected advantages of using hybrids with irrigation and fertilization (based on soil analysis), the importance of adapting planting time and technologies (such as rate, timing and frequency of irrigation and fertilization) to site specific conditions is highlighted as the limitations of this study. While mechanization, and improved variety and management practices can improve efficiency of cereals production, the energy cost has to be balanced with increased productivity and income.

References

[1] GUSMÃO, M. F. G., SILVINO, L., HELDER, H. M., & ARIA, F. P. M. (2017). Bobonaro em Numeros Estatistica Municipio de Bobonaro.www.statistics.gov.tl.

[2] LOPES, M., & NESBITT, H. (2012). Improving Food Security in Timor-Leste with Higher Yield Crop Varieties. Paper prepared for presentation at the 56thAARES. Annual Conference, Fremantle, Western Australia.

[3] LU, J., WANG, D., & LIU, K. (2020). Inbred varieties outperformed hybrid rice varieties under dense planting with reducing nitrogen. *Sci Rep* 10, 8769. https://doi.org/10.1038/s41598-020-65574-0

[4] ISHIMARU, T., NAKAYAMA, Y., AOKI, N., OHSUMI, A., SUZUKI, T., UMEMOTO, T., YOSHINAGA, S., & KONDO, M. (2018). High temperature and low solar radiation during ripening differentially affect the composition of milky-white grains in rice (Oryza sativa L.), Plant Production

Science, 21:4, 370-379,

[5] YANG, Y., ZHANG, M., LI, Y., & GENG, Y. (2012). Controlled Release Urea Improved Nitrogen Use Efficiency, Activities of Leaf Enzymes, and Rice Yield Nutrient Management & Soil & Plant Analysis Extent of Use and Optimization of Applications of CRU in Cereal Crops. Research Journal Publication, University of Florida. https://www.researchgate.net/publication.