Nitrogen contribution from forage legumes in maize farming system in West Timor, Indonesia

Evert Hosang[1], Jacob Nulik[1], Debora Kanahau[1], Yandri Abi[1] and Lindsay Bell[2]

[1] NTT Assessment Institute for Agriculture Technology, Naibonat, Indonesia, Email: yulianeshosang@yahoo.co.id
[2] CSIRO, 203 Tor St, Toowoomba Qld 4350, Australia.

Abstract
Maize is the important staple food crop cultivated in West Timor, Indonesia. However, maize productivity in West Timor is low (2.7 t/ha in 2010) compared to the national average (4.2 t/ha in 2010), due to low use of fertilisers. Integrating forage legumes into maize cropping systems has the potential to assist in improving maize nutrient supply and also provide high quality forage for livestock. The experiment was conducted on the island of West Timor, Indonesia to evaluate biomass production of herbaceous forage legumes in West Timor environment and to quantify potential nitrogen contribution from forage legumes in to maize in a rotation farming system. Butterfly pea, and Centro (both varieties) produced the most biomass (>6 t DM/ha), estimated shoot N was >150 kg N/ha and had the largest impacts on growth of a subsequent maize crop. Growing legumes and retaining their biomass on the field contributed significant nitrogen supply to the following maize crop, increasing N uptake by 30-50 kg/ha. Grain yields of a following maize crop were increased by 50% (1.4-1.6 t/ha) where legume was cut and removed, and by 90% (2.6-2.8 t/ha) where legume biomass was retained. This study has shown that Butterfly pea and Centro, can be used in legume-maize rotation farming system in West Timor to improve soil fertility and increase maize production.

Key Words
Nitrogen, forage, legume, maize, West Timor, Indonesia

Introduction
East Nusa Tenggara (ENT) is one of Indonesia's poorest provinces, with around 60% of the population living in poverty (<US$2/day) and over 40% of households food insecure (FAO, UNICEF, WFP Joint Report, 2010). Maize is the important staple food crop cultivated in West Timor, Indonesia. However, maize productivity in West Timor is low (2.7 t/ha in 2010) compared to the national average (4.2 t/ha in 2010) (Statistical Year Book of Indonesia, 2011). This is partially due to low use of fertilisers as a consequence of low farm capital. Significant gains have been shown to be possible through improved nitrogen supply (Hosang, 2014; Dalgliesh, et al, 2008; Budisantoso, et al, 2007), however, access to, and ability to pay for synthetic N fertilisers is often limited.

Integrating forage legumes into maize cropping systems has the potential to assist in improving maize nutrient supply and also provide high quality forage for livestock. A small suite of promising annual and short-lived perennial tropical forage legumes such as *Clitoria ternatea* (Butterfly pea), *Lablab purpureus* (Lablab, Dolichos) and *Centrosema pascuorum* (Centro) have been identified as being suitable for this purpose and are adapted in the region. However, information about the potential N inputs of these forage legumes and their impacts on subsequent maize yields in West Timor has not been examined. Moreover, cutting and removing legumes for livestock feed may influence the N contribution that the legumes provide to subsequent maize crops.
The objectives of this experiment were:

1. to evaluate biomass production and potential N inputs of herbaceous forage legumes in West Timor environment
2. to quantify maize growth and grain yield responses following herbaceous forage legumes in West Timor, Indonesia
3. to assess the impact of cutting and removing legume shoot biomass for livestock feeding on the residual N available for subsequent maize crops.

Methods
The experiment was conducted on a vertic-inceptisol soil in Naibonat village, West Timor of Indonesia. The experimental site was prepared for two growing seasons prior by sowing a forage sorghum and repeatedly cutting and removing to run-down soil mineral N status. The experiment applied split-plot design with main plots (24 × 5 m) involving 5 legume treatments and a maize control and split-plots (12 × 5 m) of removed or

retained forage legumes and 4 replications. Five forage legumes, *Clitoria ternatea* (Butterfly pea). *Lablab purpureus* (Lablab, Dolichos), *Centrosema pascuorum* cv. Cavalcade, CP var Bundayand *Glycine max* (Soybean) were grown in 2014/15 (Dec 14-Jul 15) and a control of *Zea maize* (maize cv. Lamuru) was also grown (Dec 14-Apr 15). Because of dry conditions during the 2015 wet season, some additional irrigation (180 mm total) was applied at 2 weekly intervals until early April 2015. At flowering, the forage legumes were either, cut and removed from the plot area, or left uncut and their residue was retained on the soil surface. Legume shoot biomass was measured at each cutting or at maturity; two cuts were taken from Butterfly pea, and only a single cut from the Lablab, Soybean, and Centro. At maturity the maize was harvested and stover removed from plots.

The experiment was maintained weed-free and recruitment/regrowth of legumes controlled with applications of Glyphosate (2 L/ha) prior to sowing the second year maize crop (cv. Lamuru) on 27 December 2016. This crop was entirely dryland after sufficient soil moisture had accumulated after the beginning of the wet season. All crops received two rounds of hand weeding 4 weeks after planting and 10 weeks after planting. Maize was sown on 80 cm row spacing with 20 cm between plants. Six weeks after sowing a basal application of 100 kg of urea per hectare was applied adjacent to each maize plant. A shoot sample was taken from 3 m of row to determine anthesis biomass. Maize was hand harvested in April 2016 from an area of 7.2 m^2 (9 m of row) within each plot, the number of cobs per sample recorded, and a subsample of 10 cobs taken and threshed to determine grain yield.

Soil water and nitrogen status were measured at the end of the legume, prior to sowing of the following maize and after the second maize crop (data have not been fully analysed so are not presented here). Legume shoot *Ndfa* and N concentration, and maize shoot N concentration are to be analysed but had not been completed at the time this paper was prepared.

Results & discussion

The forage legumes, Butterfly pea and Centro (both varieties) grew well and produced the highest biomass, while Lablab and soybean performed poorly (Table 1). It is unclear what constrained growth of lablab and soybean, but it may have been related to insect damage, poor nodulation and N fixation; legume seeds were not inoculated with root nodule bacteria at sowing. Butterfly pea and Centro have been reported by Dalgliesh et al (2008) to have the highest biomass production potential in this region; this study further supports that these two species are the most reliable and suited for use in rotation with crops.

Table 1. Dry matter (DM) production from the five tested legumes and estimated above ground N accumulation (assumed N content of 2.5% N in all legumes). Letters denote significant differences (*P*<0.05) between species.

Species	Dry matter biomass (t/ha)	Above ground N accumulation (kg/ha)
Clitoria ternatea cv. Milgarra	6.7 b	168
C. pascuorum cv. Bundey	7.3 a	184
C. pascuorum cv. Cavalcade	7.4 a	184
Lablab purpureus cv. Highworth	2.1 c	53
Soybean	1.4 c	34

Based on assumptions of N concentration in the legumes this shows that the legumes can contribute to N accumulation of more than 160 kg N/ha from above-ground biomass (Table 1). Below-ground biomass was not measured here, but is likely to contribute an additional 50-100% of the shoot N reported. While we have not as yet measured the net N fixation from these legumes it is clear that Butterfly pea and Centro have fixed significant amounts of atmospheric N and contributed this to the system. So if legumes are grown prior to a maize crop and the biomass is retained on the field, there would be little need to apply any additional N fertilizer. Some forage legumes contributed enough nitrogen for maize crops in West Timor environment, supported by result of Budisantoso et al (2007). However, in these mixed farming systems the primary purpose of these legumes is to provide high quality forage for livestock, so much of the shoot material is likely to be removed from the system. Hence, understanding how much additional N is left after legume biomass is removed from the field is critical to assess the likely N benefits for subsequent maize crops.

Table 2. Maize shoot biomass and estimated N uptake at anthesis (61 das) following maize or 5 forage/grain legumes that were either cut and removed or were uncut and residue retained.

Previous crop/forage	Anthesis biomass (t/ha)		Estimated shoot N uptake (kg N/ha)*	
	Cut	Uncut	Cut	Uncut
Maize	2.2		33	
Clitoria ternatea cv. Milgarra	3.8	5.1	57	77
C. pascuorum cv. Bundey	2.2	4.0	33	60
C. pascuorum cv. Cavalcade	2.9	5.3	44	80
Lablab purpureus cv. Highworth	2.2	4.0	33	50
Soybean	1.9	1.8	29	27

* N content of maize at anthesis had not been completed, estimated to be 1.5% N

Maize biomass production following the legumes was greatly influenced by legume species and the removal of the legume residue (Table 2). Where the legume biomass of Centro and lablab had been removed, maize anthesis biomass and estimated N uptake was similar to following maize, while following Butterfly pea anthesis biomass was 73% higher than after maize. This suggests that butterfly pea leaves more below-ground N for subsequent crops than the shorter-lived annual species. The estimated additional maize N uptake at anthesis was 24 kg N/ha after butterfly pea where shoot material was removed.

Where the legume biomass was retained, the anthesis biomass of the following maize was 80% higher in the retained plots than where Centro and lablab biomass had been cut and removed. The difference was less after butterfly pea, due to higher biomass in the cut and removed treatments, but a similar anthesis biomass was achieved to following retained Centro cv. Cavalcade. Where Centro and Butterfly pea biomass was retained, N uptake by the following crop was up to 30-50 kg N/ha higher than following maize.

Table 3. Maize grain yield following maize or 5 forage legumes that were either cut and removed or were uncut and residue was retained.

Previous crop/forage	Grain yield (t/ha)		Number of cob (cobs/m^2)		Average grain per cob (g)	
	Cut	Uncut	Cut	Uncut	Cut	Uncut
Maize	2.9		10		29	
Clitoria ternatea cv. Milgarra	4.5	5.5	11	12	41	46
C. pascuorum cv. Bundey	4.5	5.7	10	11	45	52
C. pascuorum cv. Cavalcade	4.3	5.6	10	12	43	47
Lablab purpureus cv. Highworth	3.2	4.4	10	11	32	40
Soybean	2.6	2.8	9	10	29	28

Compared to maize following maize, grain yields of maize following butterfly pea and Centro were increased by 50% where their biomass was cut and removed, and were increased by 90% where legume biomass was retained. This response was primarily due to increase in cob size with only small effects on cob number due to these treatments. Maize yield following soybean were similar to following maize, due to the low legume growth and N inputs measured in the previous year. Maize yield following lablab was intermediate between the other legumes and maize; yield increased little where lablab was cut and removed (10%) and by 50% where lablab had been retained. Differences in maize grain yield between cut and uncut treatments were less evident than for anthesis biomass. Grain yields were 1.0-1.3 t/ha higher where forage legume biomass had been retained on the plot.

Conclusion

This research has confirmed that both Butterfly pea and Centro were well suited to rotations with maize in farming system in West Timor, Indonesia. Large increases in grain yield of > 2.5 t/ha, 90% greater than maize after maize, were seen where the legumes biomass was retained in the field. But these legumes were still able to provide grain yield benefits of around 1.5 t/ha when their biomass had been cut and removed indicating that some N nutrition benefits are still being provided even if they are being cut for forage for livestock. Given that only a proportion of the N accumulated in legume biomass has been accounted for in the following maize crop, it is anticipated that further benefits might persist in subsequent crop years. This will be investigated in coming years.

References

Soeharinoto, H, Fernandez, P Th, and Ratnawati, S, 2012. Evaluation of Legume Herbs Nutritive Value as a Ruminant Feed and Nitrogen Supply on Soil in West Timor, Indonesia. Pakistan Journal Agric Res. Vol 24. No. 4.

Dalgliesh, N P, Budisantoso, E, Darbas, T, Ngongo, Y and Whish, J, 2008. Developing a Strategy for Improved Crop and Animal Production in the Semi-arid Tropics of West Timor, Proceedings of 14th Australian Agronomy Conference, Adelaide.

Budisantoso, E, Dalgliesh, N P, Fernandez, P Th, Basuki, T, Hosang, E, Kana hau, D, and Nulik, J, 2007. The utilization of Stored Soil Moistures for Forage Legumes Supply in the Dry Season in West Timor, Indonesia. International Grassland s Congress. Tibet.

FAO, UNICEF, WFP Joint Report, 2010. Nutrition Security and Food Security in Seven Districts in NTT Province, Indonesia: Status, Causes and Recommendations for Response. Final Report, February 2010. http://documents.wfp.org/stellent/groups/public/documents/ena/wfp236825.pdf

Statistical Year Book of Indonesia, 2011. BPS. Satistik Indonesia 22nd March 2016. <http://www.bps.go.id/tnmn_pgn.php?eng=0>