The use of forage legumes in cereal cropping systems of Eastern Indonesia

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Abstract

Annual average rainfall for the Eastern Indonesian province of East Nusa Tenggara (ENT) ranges between 1000 and 2000 mm. However, subsistence farmers in ENT often face food shortages during the late dry and early wet seasons (September-November). Yields of maize, the main food security crop of the farming community, are generally low, as a result of poor crop nutrition and sub-optimum agronomic practices. Cattle, which enable farmers to access the broader cash economy, suffer from feed shortages in the late dry season, resulting in low and variable liveweight (LW) gain. The inclusion of annual and semi-perennial forage legumes, grown in relay or rotation with maize, provide the opportunity for improvements to both the crop and animal components of the farming system. The legumes, including Butterfly Pea (*Clitoria ternatea*) and Cavalcade Centro (*Centrosema pascuorum*), access otherwise underutilised soil moisture, available at the end of the wet season, to produce high-quality feed for livestock, and provide soil nitrogen (N) for use by subsequent maize crops. Cattle supplemented with forage legumes during the dry season (April-November) had greater LW gain (240 g/day) than cattle that were fed traditionally using locally available feedstuffs (150 g/day). Maize grain yields were 0.75 t/ha greater in crops grown after a season of relay-cropped forage legume, with no application of inorganic fertiliser, compared to maize grown after a dry season weedy fallow.

Whilst the results of the biophysical research show positive benefits, subsistence farmers are unlikely to invest unless the risks associated with the new technology are no greater than those of existing practices. An evaluation of research impact in collaborating villages suggests that the point has been reached where farmers are prepared to invest in forage legumes, primarily as a response to increased demand for quality animal forage, but also as a result of the small, but significant improvements in maize production.

Key Words

Forage legumes, stored soil water, nitrogen fixation, subsistence farmers, on-farm research

Introduction

The upland farming systems utilised by subsistence farmers in West Timor, part of the Eastern Indonesian province of East Nusa Tenggara (ENT), are based on the production of maize and pulses. Crops are grown under dryland conditions during the short annual wet season (from December to April) with the land left fallow, or used for opportunistic grazing during the subsequent dry season. Lowland rice production using supplemental irrigation further supports food security. Whilst the average annual rainfall for the regencies of Kupang, Timor Tengah Selatan (TTS), Timor Tengah Utara (TTU) and Belu is above 1000 mm, inter- and intra-seasonal variability is high. As a consequence, the use of traditional landrace maize lines, low or non-existent use of fertiliser and sub-optimal agronomy, the average provincial maize yield of 2.5 t/ha is lower than the national average of 3.7 t/ha (Statistics Indonesia 2010). The combination of low yields, small farm size (0.5 – 1.5 ha) (Darbas pers. comm.) and large households (average of 6 family members) (Suek, pers. comm.) often results in late dry-season food shortages (from September to November).

To service the increasing demand for beef from the Indonesian population centres of Java and Sumatra, cattle ownership within the subsistence farming community is being promoted by both the government and by non-government aid organisations. Farmers also see cattle ownership, primarily for live inter-island export, as an attractive option as it provides entry to the cash economy and the resources necessary to meet education, medical and social expenses. However, as a result of the poor quality and availability of forages during the dry season, cattle growth rates tend to be low and erratic. Research in the period 2006-08 identified legumes well-adapted to the environment and capable of producing significant quantities of biomass using otherwise underutilised soil water resources (Budisantoso et al. 2008; Dalgliesh et al. 2008). Recent research has focussed on examining the potential to integrate the forage legumes into the system from both the biophysical and social perspectives.

Methods

A participatory research approach involving farmers in the villages of Oebola and Usapinonot (Table 1) was used to test the hypotheses that forage legumes, grown in relay (sown as the maize crop reached anthesis) or in rotational sequence with maize, would contribute to system N supply and provide biomass for animal production.

Table 1: 2008-09 on-farm research sites in West Timor, Indonesia: Geographical and environmental conditions.

Regency	Village	Latitude, Longitude	Elevation (m ASL)	Annual Rainfall (mm) and rainfall pattern	Soil Type
Kupang	Oebola	-10.069, 124.006	440	1000 - unimodal	Vertisol
TTU	Usapinonot	-9.452, 124.544	360	1500-2000 - unimodal	Vertisol

Relay

At each site, a randomised split-plot experimental design consisting of 3 replications and 4 main plot treatments (10 x 5 m) was used. Main plots comprised each of the legumes, Butterfly Pea, Cavalcade Centro and Lab Lab (*Lablab purpureus*) and a sole maize control. In December 2007 the open pollinated maize variety ‘Lameru’ was sown across the trial area at a population of ~60,000 plants/ha. Sowing was by hand with 2 seeds planted every 40 cm in 80 cm rows. No fertiliser was applied to the crop. When the maize reached anthesis in February/ March 2008, the legume treatments were imposed. Rows of legume seed were planted 20 cm either side of each maize row. Seed was sown at a depth of 2 to 3 cm and at a spacing of 25 cm (equivalent to a sowing rate of 5 kg/ha). The maize was harvested in late March/early April 2008 with the legumes growing through to senescence or until they ceased producing significant quantities of biomass. Legume biomass was measured every 4-6 weeks during this period. Remaining legume biomass was not removed at the end of the growing period.

In the following wet season (2008/09) a maize bioassay was used to determine the contribution of legume N to subsequent cereal production. Maize variety, population and plant configuration remained as for the previous season. Main plots were each divided in two with half receiving nil fertiliser and the other 100 kg/ha N (applied as urea). Half of the fertiliser was applied at sowing and the remainder 30 days later. Regenerating legumes and other weeds were controlled through regular hand weeding. Grain and stover yield were measured at maize maturity in late March 2009. Sampling for soil water and mineral nitrate was undertaken prior to sowing and after maize harvest.

Rotation

At Usapinonot, a similar experimental design and monitoring protocol to that described above was used to investigate the potential for legumes to be used in rotation with maize. Legumes were sown into fallowed land in February 2008.

Animal production

Animal feeding trials were undertaken in both villages during the 2008 dry season (April to November). Male Bali (*Bos sondaicus*) calves (n=15; approximately 6 months of age and 69 and 99 kg LW in Usapinonot and Oebola, respectively) were allocated to one of three treatments. The treatments were control (maintained under prevailing management conditions which typically involved tethering calves on communal lands to graze any available material) or locally available feedstuffs supplemented with either 15 g dry matter (DM)/kg animal LW per day forage legumes (a combination of Butterfly Pea and Cavalcade) or the shrub legume Leucaena (*Leucaena leucocephala)*. The calves that received supplements were maintained in individual stalls within a communal village feedlot. The forage legumes were ‘cut and carried’ and supplied fresh each day in the early to mid dry season and as hay as the dry season progressed. The leucaena was supplied as fresh ‘cut and carry’ for the full feeding period. Animals were weighed every 2 weeks.

Results

Legume biomass production – under relay conditions

Due to the slow initial growth rate of relay-cropped legumes under the maize sward, biomass yields of Butterfly Pea, Cavalcade and Lab Lab were low. In Oebola, Butterfly Pea and Cavalcade yielded ~0.4 t/ha DM and Lab Lab 1.2 t/ha DM. Whilst the soil water profile was at field capacity at time of legume flowering in May (80 days after sowing; DAS), the Lab Lab and Cavalcade began to senesce soon after and were unable to utilise available resources effectively. Butterfly Pea continued to grow and utilise available soil water but was unable to produce significant biomass before water resource depletion in late June (111 DAS). In Usapinonot the situation was similar, with Cavalcade yielding 0.4 t/ha, Butterfly Pea 0.8 t/ha and Lab Lab 1.1 t/ha DM.

Legume biomass production – under rotation conditions

The rotation trial at Usapinonot, planted on the same day as the relay-cropped legumes, produced significantly more biomass than the latter. Cavalcade yielded 5 t/ha, Butterfly Pea 1.1 t/ha and Lab Lab 2 t/ha DM. Whilst these data show that Butterfly Pea yielded less than Cavalcade, biomass from Butterfly Pea was removed without permission by farmers three times during the season, presumably to feed animals.

As water was non-limiting in the early growing season, it is assumed that competition for light between maize and legumes played a significant role in the differences in biomass production between the two systems. This hypothesis is supported by the data, with Cavalcade under relay conditions producing 0.2 t/ha DM in the first 75 DAS compared to rotation crops where the legume produced 2.7 t/ha DM over the same period (observed in adjacent experiments).

Maize yield as a response to legume production

Whilst the maize bioassays undertaken during the 2008/09 season showed that there were N benefits to subsequent cereal crops from legume use, there was a high level of variability within trials and between sites. In Oebola, after relay-cropped Butterfly Pea and Cavalcade with no applied N fertiliser, maize grain yields increased on average by 0.7 and 0.9 t/ha (dry weight basis) respectively, compared to the sole maize yield of 2.6 t/ha (Figure 1). Stover yields in both cases increased by 1 t/ha above the sole maize yield of 3.4 t/ha. Where N was applied (at 100 kg/ha N), the sole maize grain yield increased to 4.9 t/ha with Butterfly Pea and Cavalcade contributing an additional 1.8 and 1.4 t/ha yield, respectively. Maize grown after Lab Lab did not show a response to the presence of the legume.

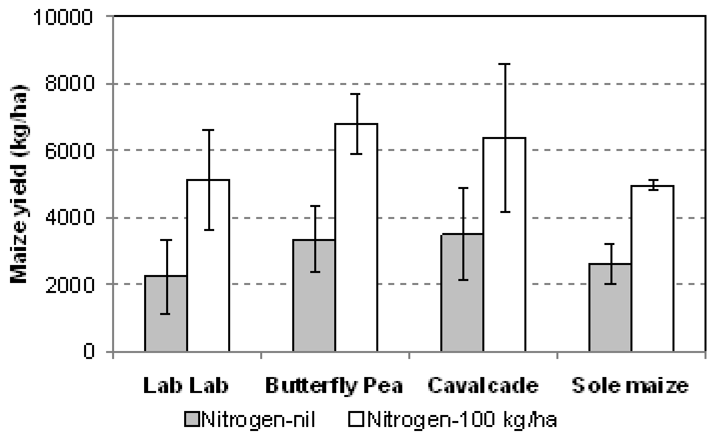

Figure 1: The impact of Nitrogen fixed by relay cropped forage legumes (2007/08) on subsequent maize grain yield at Oebola, West Timor (2008/09)

Maize yields in Usapinonot are historically lower than Oebola. Whilst the reasons are yet to be clarified it is considered that a combination of soil type, nutrient deficiency and disease are likely to be the main contributors. Maize grain yields after relay-cropped Butterfly Pea increased by 0.2 t/ha compared to the maize control of 0.6 t/ha. Stover yields were similar at 1.2 t/ha. With the application of 100 kg/ha N, grain yields increased to 1.5 t/ha for the sole maize and 1.2 t/ha after Butterfly Pea. There was little contribution to grain yield from either Cavalcade or Lab Lab. Cavalcade grown in rotation at Oebola achieved a legume biomass yield of 5 t/ha DM which subsequently translated into an increase in maize grain yield of 0.5 t/ha, compared to the control yield of 1.7 t/ha. Stover yield increased by 0.4 t/ha compared to the maize control yield of 3.1 t/ha. The maize bioassay after Lab Lab and Butterfly Pea showed no response in terms of yield or stover production. In the case of the Butterfly Pea this is considered of significance as it was material from this treatment that was 'cut and carried' by farmers and therefore most closely represents the way that the legume would be used in the farming system. This contrasts to the other treatments where legume material remained on the plots into the dry season.

Animal production

Over 182 days of dry season feeding (until late September), animals at Oebola gained at a rate of 230 g/day when supplemented with forage legumes, compared to 290 g/day when fed leucaena. However, tether grazed animals grew at 360 g/day, 130 g/day faster than when fed the forage legumes and over twice the rate of tethered animals in Usapinonot. Investigations showed that the presence of a local indigenous legume was likely to be contributing to the improved outcomes in the unsupplemented group at Oebola. Identification of the legume is currently under way with a view to investigating its future systems use. In Usapinonot, cattle supplemented with a mix of Butterfly Pea and Cavalcade for 210 days, gained 240 g LW/day (51 kg LW over the dry season) compared to 'tether grazed' animals that gained 150 g LW/day (32 kg LW over the dry season). Cattle fed leucaena gained 330 g LW/day (69 kg LW over the dry season) (Figure 2).

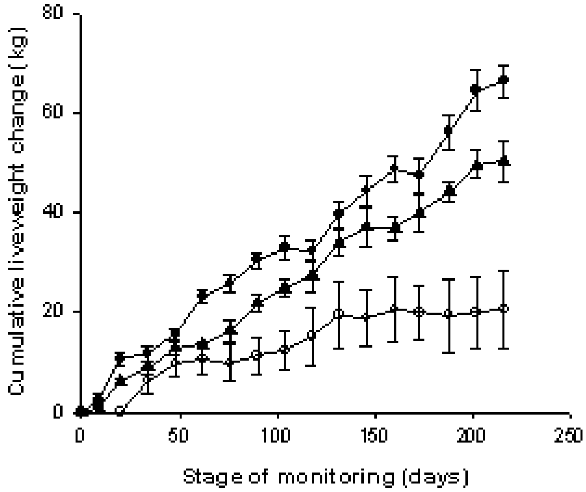

Figure 2: Cumulative live weight change of Bali calves, unsupplemented and tether grazed (○), or supplemented with forage legumes (▲) or leucaena (●) between April and November 2008 in Usapinonot village, East Nusa Tenggara Province.

Discussion

Whilst there is promising evidence that the adoption of forage legumes in maize-based farming systems can impact positively on animal production, benefits to maize production, through increased N fixation, are less clear and require further research. The most positive aspect to the research are the changes in farmer practice occurring where animal feed supply is limiting expansion of animal production. Farmer groups are making the decision to grow legumes to meet the demand for better quality and more consistent supply of forage, driven by increasing animal ownership which is primarily a result of improved access to government supported animal credit schemes. Whilst increasing demand for forage legumes is a positive indicator of impact, the fact that farmers are now considering legume production in a strategic sense, tailoring use to best fit their own requirements, indicates that they are on the way to adopting legumes as a longer-term component of their farming system and not just an artefact of project involvement. An example of where this is occurring is the village of Usapinonot where relay-cropped legumes are being fed to animals during the wet and early dry seasons, and browse legumes utilised during the late dry season. This is a complete reversal to what was considered logical by researchers during the design of the project.

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