

Early Sowing of Grain Legume Crops after Rice Harvest Increases Grain Yield

Marcial Gusmao

Department of Agronomy and Centre for Climate Change and Biodiversity, Faculty of Agriculture,
National University of Timor Lorosa'e, Timor-Leste

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Abstract Most paddy fields in Timor Leste are abandoned after harvesting the rice crop due to limited supplemental irrigation. Other field studies have identified some drought-adaptive grain legumes including kidney bean (previously grown in cold, highland areas only), Ceora grass pea (*Lathyrus sativus* L., a newly introduced species), mung bean, and soybean for growing after rice harvest. The impact of sowing date on growth and yield after rice harvest is not well understood. The current study aimed to identify the appropriate sowing time of grain legumes after rice harvest. Seeds of kidney bean and grass pea were sown in plots arranged in a randomized block design with three factors (species, drought treatment, and sowing date) and three replications. There were three sowing dates at monthly intervals: 28 May (D1), 28 June (D2) and 28 July 2017 (D3). The terminal drought treatment was applied at first flower of grass pea or pod set of kidney bean for each sowing date. Overall, kidney bean produced more seed yield (32% higher) than grass pea. Yields of both species decreased at the later sowing dates ($P<0.001$). Grass pea produced 78% more filled pods than kidney bean, but 34% fewer seeds per pod and 58% smaller seeds than kidney bean. Seed weight in both species decreased at later sowing dates as did seeds per pod in kidney bean, but grass pea maintained seed numbers per pod at all sowing dates. Dry matter production between species was comparable, which declined at later sowing dates ($P<0.001$). In conclusion, early sowing of grain legumes produces more seeds and biomass after rice harvest than late sowing.

Keywords Paddy Field, Grain Legumes, Grass Pea, Kidney Bean, Sowing Dates, Terminal Drought, Yield

1. Introduction

Most paddy fields in Timor Leste are abandoned after rice harvesting due to limited supplemental irrigation.

Other field studies have identified potential drought-adapted grain legumes including kidney bean, grass pea, mung bean, cowpea and soybean for cropping after rice harvest (Gusmao, 2016, 2017). Gusmao (2017) reported the adaptation of kidney bean (previously grown in cold, highland areas only) and grass pea (*Lathyrus sativus*) to new production environments. The study concluded that kidney bean, with its determinant growth habit, could be grown in lowland, coastal areas during the dry season. Cultivars Ceora and Cicera of grass pea (*Lathyrus sativus*), with indeterminant growth habits, are new to Timor Leste (introduced by Dr. Marcial Gusmao from Australia) and reportedly well-adapted to this environment (Gusmao, 2016, 2017). However, Cicera is reportedly adapted to the highlands only, while Ceora which was developed at the Centre for Legumes in Mediterranean Agriculture (CLIMA) at the University of Western Australia (Siddique et al., 2006) is adapted to both the highlands and lowland, coastal areas. Kidney bean and grass pea have the potential to grow using the residual water in the paddy field for grain production after rice harvest. The appropriate sowing time for grain legumes after rice is not well understood but is important for maximizing grain yield after rice harvest. Thus, identifying the appropriate sowing time for grain legumes would help to manage rice sowing dates and thus harvest.

2. Research Objectives

This study aimed to identify the impact of sowing date on growth and yield of kidney bean and grass pea cultivar Ceora and the appropriate sowing date of the grain legumes after rice harvest.

3. Research Methods

Research Design, Site, Land Preparation

The study was conducted in a horticultural area of

Manleuana (previous rice production area), Dili, Timor Leste using a randomized block design with three factors (species, drought treatment, and sowing date) and three replications.

The land was prepared in May 2017 to create 12 plots (each 180 × 140 cm) for each of the four sowing dates (detail below).

Sowing

Two grain legumes—kidney bean and grass pea (*Lathyrus sativus* cv. Ceora)—were used in this study. The kidney bean seeds came from a local farmer in the Quelicai highland, Baucau Municipality and represented a determinate growth habit species. The Ceora seeds came from previous trials in Timor Leste (Gusmao, 2016, 2017)—as the species had been recently introduced by Dr. Marcal Gusmao from Australia—and represented an indeterminate growth habit species. The kidney bean and grass pea seeds were sown at monthly intervals on 28 May (D1), 28 June (D2), 28 July (D3), and 28 August (D4) 2017. Sowing at D4, however, did not produce any yield due to damage from the onset of rain and was not included in the results. For each sowing date, three kidney bean seeds were sown in each hole and thinned to two seedlings per hole when established. The grass pea seeds were germinated first (on the same sowing dates) with two plants transplanted into each hole when the seedlings were well-established. The planting distances were 25 cm by 20 cm in both species.

Watering and Drought Treatment

Plots were watered using hand sprayer, a day before sowing of seeds, to bring the soil moisture to approximately field capacity. Watering continued regularly until the reproductive stage where terminal drought was initiated. The terminal drought applied to both species at the same time at which kidney bean plant was at its podding stage, while grass pea was at its first flowering stage. The control plants were well-watered until maturity.

Yield and Yield Component Measurements

Plants were harvested when they reached 90–100% physiological maturity. Eighteen above ground plants were harvested from a 50 × 40 cm area (0.20 m²) within each plot. Five of the 18 plants were randomly selected for measurements including numbers of plant nodes, branches, filled pods, empty pods and seeds per pod, and plant height. The seeds were separated from the pods and counted. The pod walls were added to the other plant components and oven dried at 75°C for 48 h before being weighed. The seeds remained in the oven for a few more hours to ensure

that they were well-dried before being weighed. One hundred seeds were randomly selected and weighed for seed size determination. The total seed dry weight was summed with the plant dry weight to obtain total aboveground dry matter production.

4. Analysis

The data were analyzed using the statistical package of Genstat 10 to compare growth and yield between species, sowing dates, and drought treatments.

5. Results

There were no three-way interactions of Species*Treatment*Date, except for seed weight (Fig. 1). There were many two-way interactions of Species*Date in the parameters measured (Tables 1 and 2). In general, grass pea produced 158.4 more plant nodes (170.5 nodes) than kidney bean (12.1 nodes) ($P < 0.001$) (Table 1). The number of plant nodes declined at later sowing dates (by 36% and 45% for D2 and D3, respectively, relative to D1) ($P < 0.001$). Grass pea plants were 14.5 cm taller (38.06 cm) than kidney bean plants (23.58 cm) ($P < 0.001$). Plant height declined by 26% and 30% for D2 and D3, respectively, relative to D1 ($P < 0.001$). Drought reduced plant height by 4 cm compared to the control plants ($P = 0.009$). Grass pea also produced 12.5 more branches (16.41 branches) than kidney bean (3.91 branches) ($P < 0.001$). Unlike the other parameters, branch number increased by 11% for D2, but declined by 33% for D3, relative to D1 ($P = 0.005$). Grass pea produced 17 more pods with seeds (filled pods) than kidney bean ($P < 0.001$). The number of filled pods declined by 38% and 73% for D2 and D3, respectively, relative to D1 ($P < 0.001$). Grass pea had about nine more empty pods than kidney bean ($P < 0.001$). The number of empty pods decreased by 44% and 58% for D2 and D3, respectively, relative to D1 ($P < 0.001$). Grass pea produced 0.8 fewer seeds per pod than kidney bean ($P < 0.001$). There was no treatment or date impact on the number of seeds/pod in either species. Grass pea produced lighter seeds (by 13 g/100 seeds) than kidney bean (Table 2). Seed weight declined for D2 and D3 by 17% and 36%, respectively, relative to D1. Grass pea produced 33% less seed yield than kidney bean ($P = 0.009$). The seed yield declined by 32% and 63% for D2 and D3, respectively, relative to D1 ($P < 0.001$). There were no differences in dry matter production between the species ($P = 0.294$). Dry matter production declined by 25% and 52% for D2 and D3, respectively, relative to D1 ($P < 0.001$). Terminal drought reduced dry matter production by 24% compared to control plants.

Table 1. Mean number of plant nodes, branches, empty pods, filled pods and seeds per pod, and plant height of grass pea and kidney bean under two water treatments [control (C) and terminal drought (D)] and three sowing dates (D1, D2 and D3) (P<0.05).

Species	Water treatment	Node no			Plant height, cm			No of branches			No of empty pods			No of filled pods			Seed/pod		
		D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3
Grass pea	C	239.7	135.0	153.7	52.3	32.7	40.3	16.2	21.5	14.0	12.5	6.5	6.7	42.7	22.5	9.9	1.5	1.6	1.4
	D	229.9	163.3	101.2	39.8	31.3	31.9	18.4	20.1	8.3	18.7	10.1	5.6	31.1	20.5	5.2	1.4	1.6	1.5
Kidney bean	C	16.8	10.9	11.0	28.9	27.4	17.9	4.1	3.9	3.8	5.9	1.5	1.0	5.9	5.9	3.9	2.6	2.4	2.0
	D	14.1	10.4	9.3	30.4	20.9	15.9	4.9	3.5	3.3	5.3	1.3	1.2	5.3	4.1	4.1	2.3	2.3	2.0
LSD-																			
Species		22.89***			3.560***			2.347***			1.770***			3.755***			0.1899***		
Treatment		22.89ns			3.560**			2.347ns			1.770ns			3.755ns			0.1899ns		
Date		28.03***			4.360***			2.874**			2.167***			4.599***			0.2326ns		
Species*Treatment		32.37ns			5.035ns			3.319ns			2.503ns			5.311ns			0.2686ns		
Species*Date		39.65**			6.166*			4.065**			3.065***			6.505***			0.3290ns		
Treatment*Date		39.65ns			6.166ns			4.065ns			3.065ns			6.505ns			0.3290ns		
Species*Treatment*Date		56.07ns			8.721ns			5.748ns			4.335ns			9.199ns			0.4653ns		

***significant at P<0.001, **significant at P<0.01, *significant at P<0.05, ns not significantly different

Table 2. Mean seed yield (t/ha), 100 seed weight (g), and dry matter production (t/ha) of grass pea and kidney bean under two water treatments [control (C) and terminal drought (D)] and three sowing dates (D1, D2, and D3) (P<0.05).

Species	Water treatment	Seed yield (t/ha)			100 seed weight (g)			Dry matter (t/ha)		
		D1	D2	D3	D1	D2	D3	D1	D2	D3
Grass pea	C	1.3	0.8	0.3	10.5	10.3	9.2	3.6	2.8	1.9
	D	0.9	0.5	0.1	10.2	10.0	5.3	2.6	1.7	0.8
Kidney bean	C	1.5	1.2	0.1	27.9	21.8	12.6	3.6	3.1	1.2
	D	1.1	0.7	1.0	27.2	20.5	21.7	3.0	1.9	2.3
LSD-										
Species		0.2355**			1.728***			0.513ns		
Treatment		0.2355ns			1.728ns			0.513*		
Date		0.2885***			2.116***			0.629***		
Species*Treatment		0.3331ns			2.443*			0.726ns		
Species*Date		0.4080ns			2.993**			0.889ns		
Treatment*Date		0.4080*			2.993ns			0.889ns		
Species*Treatment*Date		0.5770ns			4.232**			1.257ns		

***significant at P<0.001, **significant at P<0.01, *significant at P<0.05, ns not significantly different

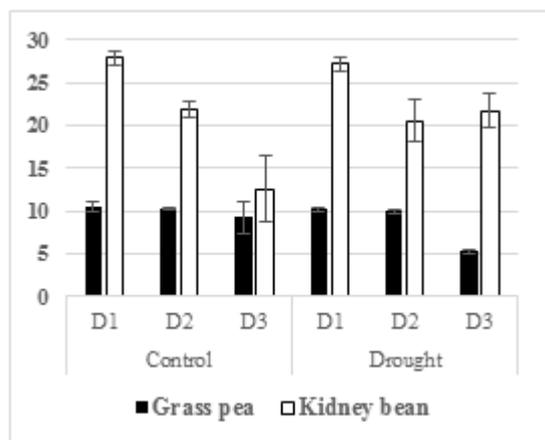


Figure 1. The interaction between species, treatment and date on 100 seed weight (g) at $P < 0.003$

6. Discussion

Other studies have identified grain legumes that can be grown after rice harvest (Gusmao, 2016, 2017). The current study investigated an appropriate time for sowing grain legumes after rice harvest using kidney bean (determinate growth habit), which had previously been grown only in the highland areas of Timor Leste, and the newly introduced grass pea (*Lathyrus sativus* cv. Ceora; indeterminate growth habit) (Gusmao et al., 2012). Kidney bean has a short growth cycle of ~72 days, while grass pea has a long growth cycle of ~115 days to maturity (Gusmao, 2017). In the current study, terminal drought had little impact on the development or yield of grass pea or kidney bean as there was minimal impact on soil water content (data not shown) and this was partly due to rainfall interruption. In contrast, the species differed in their growth and yield responses to sowing date.

In general, grass pea produced 158 more plant nodes than kidney bean (Table 1). The high number of nodes in grass pea is consistent with other field study of up to 272 plant nodes (Gusmao, 2017). With no growth restriction, a single stem of grass pea can produce up to 38 nodes (Gusmao et al., 2012). In the current study, the number of plant nodes declined in both species with the delay in sowing date, more so in grass pea (46%) than kidney bean (35%) at D3 (July sowing), relative to D1 (May sowing). A reduction in the number of plant nodes was associated with reductions in plant height and branch number. Grass pea plants were 14.5 cm taller than kidney bean. Plant height declined in both species with the later sowing dates of June and July. Terminal drought reduced plant height by 4.9 cm relative to the control plants in both species. Grass pea produced 12.5 more branches than kidney bean. Between the dates number of branches increased slightly in D2 before declining in D3. On the other hand, branch number in kidney bean declined with the delay in sowing date.

Overall, grass pea produced more pods than kidney bean

due to its higher numbers of plant nodes and branches, and taller plants. Grass pea produced 17 more filled pods than kidney bean. The number of filled pods in grass pea declined linearly from D1 to D2 to D3, while there was little change in kidney bean. Grass pea produced 8.6 more empty pods per plant than kidney bean. High empty pod numbers in grass pea have been reported in a greenhouse study (Gusmao et al., 2012) and the field (Gusmao, 2016, 2017). Empty pod numbers in grass pea also declined steadily from D1 to D2 to D3, while there was little change in kidney bean. The empty pod of kidney bean produced from current study was associated with less total pod production. When total pods produced increases, number of empty pods also goes up as shown in a greenhouse study (Gusmao, et al., 2012) and the field (Gusmao, 2016) and this may be associated with limited resources and competition among the pods (Gusmao et al., 2012).

Grass pea produced fewer seeds per pod and less seed weight than kidney bean, which resulted in lower seed yields. Grass pea had 0.8 fewer seeds per pod than kidney bean, with no differences between sowing dates or the terminal drought treatment. Interestingly, there was a three-way interaction between species, water treatment and sowing date on seed weight (Fig. 1). The 100-seed weight of grass pea was 12.7 g lower than kidney bean. Seed weight in grass pea changed little between sowing dates but declined at D3 in droughted plants. Sowing time at D3 was probably more responsible for low seed weight rather than the terminal drought. A greenhouse study reported the stability of seed size of grass pea under severe water deficit conditions during reproductive stage (Gusmao, et al., 2012). In contrast, seed weight in kidney bean declined steadily from D1 to D2 to D3, with a similar pattern in droughted plants, apart from a slight increase from D2 to D3. Similar seed weights between droughted and control plants have been reported elsewhere (Gusmao, 2016). The increased seed weight in droughted kidney bean suggests its adaptive response to water deficit as reported by Blum (1996) and Ludlow and Muchow (1990).

In general, this study produced lower grass pea and kidney bean yields than other field studies (Gusmao, 2016, 2017), ranging from 1.3 t/ha at D1 to 0.1 t/ha at D3 in grass pea and 1.5 t/ha at D1 to 0.3 t/ha at D3 in kidney bean compared with 2.8 and 2.0 t/ha for kidney bean and grass pea, respectively (Gusmao, 2017). In the current study, kidney bean yielded 0.3 t/ha more than grass pea, due to its higher seed number per pod and seed weight. Kidney bean had an advantage over grass pea due to its earlier maturity (~72 days after sowing) (Gusmao, 2017), which could be associated with better yields particularly in water limited environment during the reproductive stage (Muchow, 1985; Leport et al. 1998; Ludlow and Muchow 1990; Siddique et al. 2001). In the current study, yields of both species steadily declined with the delay in sowing date, which was associated with fewer pod numbers and seeds per pod, and is consistent with a study on various grain legumes

(Muchow, 1985). A reduction in seed weight and seed yield at later sowings in high land environments has been reported for common beans (Acosta-Gallegos et al., 1996).

Dry matter production did not differ between species, which is consistent with another study by Gusmao (2016), but steadily declined with the delay in sowing date. The terminal drought treatment reduced dry matter production in both species. When water deficit during the reproductive period is severe, a rapid growth and development of grain legumes is important. Remobilization of pre anthesis carbon and nitrogen during water deficit can support seed filling as reported in chickpeas (Davies et al., 1999; Davies et al., 2000).

7. Conclusions

Early sowing increased seed yield and biomass production in grass pea and kidney bean sown after rice harvest. Kidney bean had an advantage over grass pea with its higher seed yield and earlier maturity.

Acknowledgements

The research was funded by the Australian Alumni Small Grant Fund. I thank my field staff Domingos Pinto and field labor Belarmino da Costa and other temporary workers for their hard work during the research activities. I also thank Professor Kadambot Siddique for critical comments on the manuscript and language editing.

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