

Initial growth performances in leguminous cover crop - *Dendrocalamus asper* integration

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ABSTRACT

The association between leguminous cover crops and main crops is known to have multiple benefits. Leguminous cover crops are common in the plantations of economic crops of oil palm, rubber and coconut, but are less studied for plantations of *Dendrocalamus asper*, or Buluh Betong. This study was carried out at Ladang Sungai Jernih, Kerling, Selangor, with the aim of evaluating an effective leguminous cover crop species in supporting the growth of *D. asper*. In this work, *Pueraria phaseoloides* var. *javanica*, *Calopogonium mucunoides*, and *Centrosema pubescens*, were respectively integrated with *D. asper*, each was combined with and without the application of nitrophoska for *D. asper* after field planting. Results show that *C. pubescens* was the most potent leguminous cover crop for enhancing the growth of *D. asper* without nitrophoska supplement. By six months after planting, *D. asper* integrated with *C. pubescens* had a height of 185.96 ± 27.93 cm and tiller size (diameter) of 2.08 ± 0.40 cm, being comparable ($P > 0.05$) to the nitrophoska fertilized *D. asper* at no leguminous cover crop integration (206.94 ± 37.78 cm in height; 2.01 ± 0.26 cm in diameter). Likewise, *C. pubescens*-*D. asper* integration also had positive effects for clump development of *D. asper*; the clump area was 400.47 ± 68.34 cm² by six months after planting, being comparable ($P > 0.05$) to nitrophoska fertilized *D. asper* at no leguminous cover crop integration (343.54 ± 39.72 cm²), while *C. pubescens*-*D. asper* integration supplemented with nitrophoska had significantly ($P < 0.05$) the largest *D. asper* clump size of 494.01 ± 76.70 cm² at this point of time. However, *C. pubescens* had a slow initial growth rate with field seeding. Alternatively, *P. phaseoloides*, which showed vigorous growth of vines and fast ground cover, could be mixed with *C. pubescens* for more positive impacts in fertilizer-saving and environmentally friendly *D. asper* plantations.

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1. INTRODUCTION

Dendrocalamus asper (Schult. & Schult.f.) Backer, or commonly known as Buluh Betong, is an important plant species in human living for construction materials, utensils, sources of food and energy, clothing, medicine, recreation, and raw materials for industries such as pulp, paper, and wine (Mustafa et al., 2021; Vorontsova et al., 2016). It belongs to the Poaceae family. Thus, it is neither a tree nor a timber, although it can grow up to 20 m, having tillers of up to 15 cm in diameter, 20–45 cm long internodes, and relatively thick walls (Hossain et al., 2018; Liese and Köhl, 2015; Zheng et al., 2020).

With declining *D. asper* availability following increasing restrictions on extracting plants from natural forests in Malaysia, domestication of this non-timber crop in plantations is a valuable alternative to a sufficient and consistent supply of raw materials with this plant (Hossain et al., 2016; Hossain et al., 2018; Li et al., 2023). Nonetheless, cost-effective planting techniques and reduced negative impacts on ecosystems, especially under monoculture

systems of *D. asper*, are the concerns (Perumal et al., 2023). Cultural practices like integration with leguminous cover crops are among the approaches in striving for sustainable plantations. Cover crops introduced in between the planting rows of main crops are known for their benefits of elevating soil fertility, promoting soil microbial activities, diminishing soil disintegration, and preventing erosion (Fern, 2013; Hoy, 2014; Justes, 2017; Oliveira et al., 2020; Osman, 2013; Pokharel et al., 2025). Likewise, leguminous cover crops increase water availability but suppress weeds due to competitive impacts on resources, in particular light availability, and sometimes also through allelopathic effects (Campiglia et al., 2010; Khamare et al., 2022; Mudhita et al., 2016; Nurul Ain et al., 2016; Schonbeck, 2009; Wang et al., 2002). Within the nodules formed in the root system, leguminous cover crops fix atmospheric nitrogen (N) and supply it to the soil, lowering the cost of chemical fertilizers (Herath et al., 2017). The amount of N generated by leguminous cover crops may be at least 30 to 60 percent of that consumed by crops, depending on the leguminous cover crop species and the main crop species (Clark, 2012). Leguminous cover crops are common with the

economic crops of oil palm, rubber, and coconut in Malaysia, but these beneficial creepers are rarely introduced in *D. asper* plantations. Thus, this study analysed the performances of several leguminous cover crop species and their contributions to the initial stand establishment of *D. asper*. In this work, *Pueraria phaseoloides* var. *javanica*, *Calopogonium mucunoides*, and *Centrosema pubescens* were assessed for their effectiveness in enhancing the growth of *D. asper*. *Pueraria phaseoloides* and *C. mucunoides* were the cover crops commonly applied in the Malaysian estates, while *C. pubescens* was added in this study with seed availability at that time. In evaluating the viability of leguminous cover crop in integration with *D. asper*, the introduction of leguminous cover crop in the absence and with inorganic nitrophoska application for *D. asper* was also included in the experiment. It was hypothesized that different leguminous cover crops with different growth attributes could have different effects on *D. asper* in its early stand establishment. Suitable leguminous cover crop species that reduced chemical dependency in a cost-saving silviculture of this non-timber species was identified in this study.

2. MATERIALS AND METHODS

2.1 Experimental site

The study was conducted in Blok 2B, Ladang Sungai Jernih, Kerling, Selangor Darul Ehsan, Malaysia (3° 33' 2" N, 101° 34' 46" E). The main crop of the estate was *Elaeis guineensis* (oil palm), while the plantation also collaborated with Forest Research Institute Malaysia (FRIM) in rainfed open field *D. asper* planting. There were several *D. asper* planting phases in the preceding years. This leguminous cover crop-*D. asper* integration experiment was carried out in conjunction with a new *D. asper* planting phase at the beginning of 2023, as planned.

For this experiment, the area was excavated and cleared of oil palm crop debris in the last quarter of 2022. After the land clearing procedure, the site was ploughed, followed by agrochemical treatments to kill weeds and pests. The site was flat terrain. With mechanical analysis of soil samples taken randomly from the site, the soil type was found sandy loam.

2.2 Lining and plot marking

The study on the leguminous cover crop-*D. asper* integration was started in the middle of January in 2023. Similar to past *D. asper* planting practices according to collaboration agreement with FRIM, lining and *D. asper* planting point marking at 5x5 m squared spacing were initiated using bamboo sticks. Then, leguminous cover crop drills were prepared in between *D. asper* planting rows according to East-West orientation, alternated with no leguminous cover crop

drills in the next two middle lines of *D. asper* rows (Figure 1).

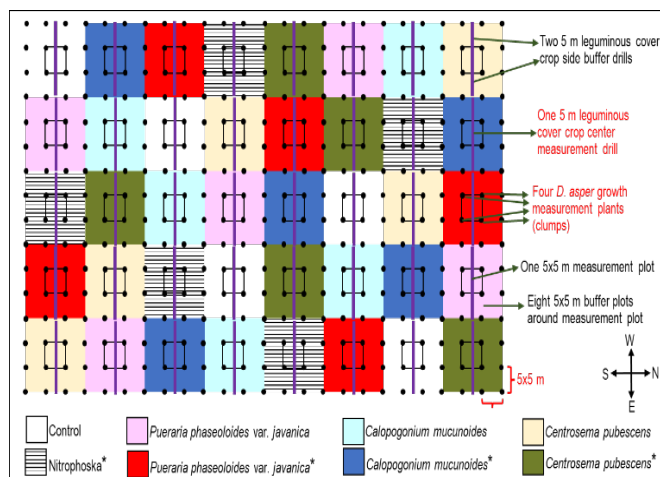


Figure 1: Treatment plots arranged in a randomized complete block design according to East-West orientation of the experimental site; * indicates nitrophoska application for *D. asper* starting from 10 weeks after leguminous cover crop seeding.

2.3 Treatment layout

Leguminous cover crops of *P. phaseoloides*, *C. mucunoides*, and *C. pubescens* were studied for possible integration with *D. asper* in this experiment (Figure 1; Table 1). Each leguminous cover crop treatment was assigned on a 5 m drill in the middle of four *D. asper* planting points. The leguminous cover crop growth measurement drills were each accompanied by the same leguminous cover crop planting at both ends as buffers; each was also a 5 m drill (Figure 1). Thus, each data collection plot of 5x5 m was surrounded by eight 5x5 m buffer plots. Each leguminous cover crop species was simultaneously studied without and with nitrophoska fertilization for *D. asper* (Table 1). Leguminous cover crop treatments were contrasted with control having no leguminous cover crop and no nitrophoska fertilization for *D. asper* (Control), as well as *D. asper* applied with nitrophoska fertilizer in the absence of leguminous cover crop (nitrophoska*) (Table 1). Each treatment was replicated five times according to East-West blocking. Thus, this experiment was based on a randomized complete block design.

Table 1: Leguminous cover crop-*D. asper* integration combined with nitrophoska application for *D. asper*.

Treatment	Leguminous cover crop species	Nitrophoska application for <i>D. asper</i> *
Control	--	--
Nitrophoska*	--	Yes
<i>Pueraria phaseoloides</i> var. <i>javanica</i>	<i>Pueraria phaseoloides</i> var. <i>javanica</i>	--
<i>Pueraria phaseoloides</i> var. <i>javanica</i> *	<i>Pueraria phaseoloides</i> var. <i>javanica</i>	Yes
<i>Calopogonium mucunoides</i>	<i>Calopogonium mucunoides</i>	--
<i>Calopogonium mucunoides</i> *	<i>Calopogonium mucunoides</i>	Yes
<i>Calopogonium mucunoides</i>	<i>Centrosema pubescens</i>	--
<i>Calopogonium mucunoides</i> *	<i>Centrosema pubescens</i>	Yes

2.4 Field seeding of leguminous cover crop

The leguminous cover crop seeding in this experiment was carried out according to in-house practices for oil palms in Ladang Sungai Jernih. For each leguminous cover crop drill of 5 m in length, leguminous cover crop seeds were mixed evenly with 100 g of rock phosphate and broadcast evenly on the drill after a rain day in the middle of January in 2023. In other words, leguminous cover crop species were introduced in the field by the direct seeding method. The seed rate for *P. phaseoloides* and *C. mucunoides* was 5 kg/ha each, or 35.71 g per 5 m drill, while that for larger *C. pubescens* was 2 kg/ha, or 14.29 g per 5 m drill. Leguminous cover crop seed weighing was done using an electronic balance. The seeds and rock phosphate were briefly covered with some soil after introduction into the drills.

2.5 Planting of *D. asper* and fertilization

At two months after leguminous cover crop field seeding, *D. asper* was transferred to the site according to the marked planting points. Tissue culture planting materials from FRIM were used in *D. asper* collaborative planting in this estate. These planting materials have been tested for uniform growth performances in past planting phases.

Preparation for *D. asper* planting materials was planned three months prior to leguminous cover crop field seeding. The tissue culture plantlets were acclimated in the nursery of FRIM according to procedures by Mohamed and Baharuddin (2015). In this context, the plantlets were transferred from the tissue culture medium to peatmoss medium in the nursery. During the acclimation period of two months, these plantlets were gradually exposed to more light, from 10% to 30% light intensity under suitable shade netting, and reduced misting frequency, from hourly misting to four-hour misting intervals. Following new shoot and root development by the end of the hardening period, the plants were transferred to a medium of top soil, burnt paddy husk, and black soil (8:1:1) supplemented with 100 g of rock phosphate in polybags sized 8"x10" (Mohamed and Baharuddin, 2015). Then, the plants in polybags were transported to the estate. In the estate, these plants were raised under 50% shade netting near the experimental site. An amount of 3 g of controlled-release nitrophoska 17:8:9 fertilizer was applied to each polybag after two weeks (Mohamed and Baharuddin, 2015).

After three months, *D. asper* plants of approximately 0.8 m in height were selected for open field planting. During field planting, each planting hole was supplied with 100 g of rock phosphate for enhancing rooting and rapid adaptation to the new growth environment (Mohamed and Baharuddin, 2015). Then, the plants were removed carefully from the

polybags and planted into the holes. The field planting was completed by filling up the holes with the field soil and having the soil around the plants slightly compacted. At this point of time, the leguminous cover crops were two months after field seeding in the drills. The germinated leguminous cover crop seeds showed initial vine elongation and ground coverage, but weeds were also growing rapidly from the weed seed bank in the soil.

For *D. asper* subjected to fertilization treatment, 80 g nitrophoska 20:10:10 was applied to each point (clump) of plant at two weeks after field planting (Mohamed and Baharuddin, 2015). The fertilizer was broadcast evenly around the clump at its dripping line (30 cm from the tillers). Subsequent fertilization for the plants, also at a rate of 80 g nitrophoska 20:10:10 per clump, was carried out at three months after the first fertilization treatment. The experiment was ended at six months after the transfer of *D. asper* to the field, when leguminous cover crop covered almost the entire field.

2.6 Stand husbandry

The experimental site was rainfed. The area generally received at least 200 mm of rainfall monthly from January to October in 2023, i.e., during the leguminous cover crop-*D. asper* integration trial (Figure 2). In other words, *D. asper* and leguminous cover crops in the field did not experience apparent drought. In terms of use of pesticides, there was no apparent pest and disease problem in leguminous cover crops and *D. asper*, and therefore, no insecticide or fungicide was applied during the study period. For weed control, *D. asper* plots without leguminous cover crop (Control and Nitrophoska*) were treated with a mixture of 260 mL herbicide containing 41% glyphosate-isopropylammonium and 50 g herbicide containing 20% metsulfuron-methyl in a 20 L tank mix at three-month intervals. The herbicidal spray volume was 300 Lha⁻¹. Plots integrated with leguminous cover crops had only spot treatments for woody shrubs twice with the same herbicides, i.e., at the 5th and 12th week after leguminous cover crop seeding.

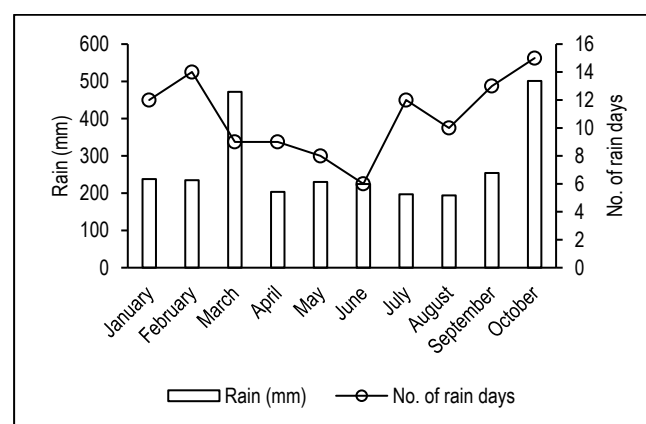


Figure 2: Rainfall and the number of rain days in January – October in 2023.

2.7. Data collection

To describe the growth performances and ground cover rates of different leguminous cover crop species, the length of the longest vines and upright growth or height of the leguminous cover crops was recorded weekly from the 5th week to the 12th week after field seeding. A measuring tape was used to determine the longest creeping vine in each leguminous cover crop measurement plot. Simultaneously, a scaled measuring pole was used to measure the upright growth or height of leguminous cover crops at three different points in each measurement plot, and the average leguminous cover crop height was calculated.

The weed species in the measurement plots were identified using a quadrat of 1x1 m at four weeks after field seeding of leguminous cover crops. Weed survey in the plots was systematically carried out according to a W-designated pattern as described by Moeini et al. (2008). The weed species data of all sampled plots were then gathered, and the relative frequencies that represented the weed types and intensities growing in the site were each calculated according to the formula below.

$$\text{Relative frequency of a weed species} = \frac{\text{Frequency value of the species}}{\text{Sum of frequency values for all species}} \times 100$$

Weekly, the weed intensity and leguminous cover crop ground cover rates within each 5x5 m leguminous cover crop-*D. asper* measurement plot were estimated visually, also from the 5th week to the 12th week after field seeding of leguminous cover crops. These two parameters were systematically estimated by the same person. Data collection on weed and leguminous ground cover rates was extended at four-week intervals to 24 weeks after leguminous cover crop seeding. To indicate the impacts of leguminous cover crop-*D. asper* integration on *D. asper*, the plants in the four planting points of each measurement plot were recorded for height, number of tillers, diameter of tillers, and clump area monthly for six months. The scaled measuring pole was used for the determination of the height of the clump in its own form. The number of tillers in each clump was counted manually. The diameter of each tiller in the clump was determined using a vernier caliper, and the average diameter was calculated. The measuring tape was used to determine the length and breadth of the clump, and the clump area was estimated as the product of the length and breadth of the clump, in view of the irregular but almost rectangular shapes of the clumps.

2.8. Statistical analysis

The data were respectively subjected to tests of homogeneity followed by one-way analysis of variance (ANOVA). Mean comparisons were carried out using Duncan's Multiple Range Test (DMRT) at 5% level of

significance. Statistical analyses were carried out using Statistical Package for the Social Sciences (SPSS) version 29.

3. RESULT AND DISCUSSION

3.1 Leguminous cover crop establishment and ground cover

With substantial rain during leguminous cover crop open field seeding, as shown in Figure 2, seeds started germination after one week. Some seeds, however, showed germination by the 3rd week. After seed germination, *P. phaseoloides* and *C. mucunoides** (but nitrophoska fertilization was not initiated before the 10th week) demonstrated faster growth of creeping vines compared to *C. pubescens* (Figure 3). After eight weeks, *P. phaseoloides* had extensive axillary growth of shoots and showed climbing behaviour, confounding vine extension rate.

For *C. mucunoides** (but nitrophoska fertilization was not initiated before the 10th week), it also exhibited rapid initial vine growth after seed germination (Figure 3). Later, fertilization on neighbouring *D. asper* that started by 10 weeks after leguminous cover crop seeding further enhanced the vine elongation of this leguminous cover crop (*C. mucunoides**) significantly. The longest vine of *C. mucunoides*, regardless of nitrophoska fertilization for *D. asper*, was more than 2.2 m by the 12th week after field seeding. On the other hand, *C. pubescens* had slower growth from seeds as compared to *P. phaseoloides* and *C. mucunoides* (Figure 3). Thus, this leguminous cover crop had significantly the least vine length growth throughout the data collection period of 12 weeks. In other words, *C. pubescens* was less effective in offering speedy initial ground cover after field seeding as compared to *P. phaseoloides* and *C. mucunoides*, as also recorded in past research work (Dissanayaka et al., 2022; Peng and Aminah, 1997; Tian et al., 2001; Venkatesan and Nandhini, 2022).

For the upright growth or height of leguminous cover crops, these three different leguminous cover crop species generally did not show great differences in this parameter from the 5th to 8th week after seeding (Figure 4). With extensive axillary shoot development and climbing habit in *P. phaseoloides* var. *javanica*, as mentioned above, this leguminous cover crop had significant height gain and offered a thick living mat in the next two weeks, i.e., by the 10th week after seeding. At this later stage in the field, this cover crop thrived well even without nitrophoska supplement for the adjacent *D. asper*; the height growth of this leguminous cover crop in plots of *D. asper* devoid of nitrophoska fertilization (*P. phaseoloides*) was not significantly different from that in the nitrophoska-fertilized *D. asper* plots (*P. phaseoloides**) (Figure 4).

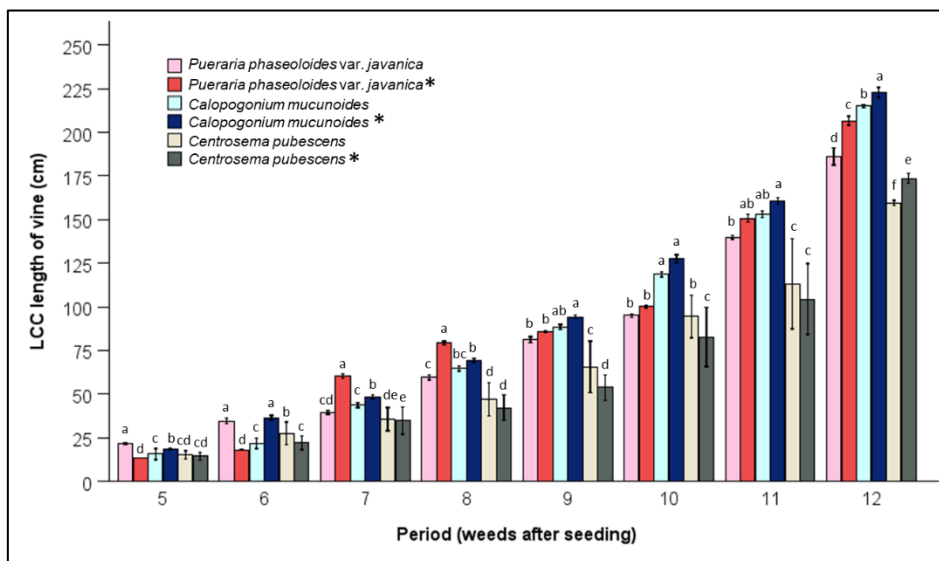


Figure 3: Leguminous cover crop vine length in cm in leguminous cover crop-*D. asper* integration; bar represents SE; * indicates nitrofoska application for *D. asper* starting from 10 weeks after leguminous cover crop seeding; means having similar letter within period are not significantly different at 5% level of significance.

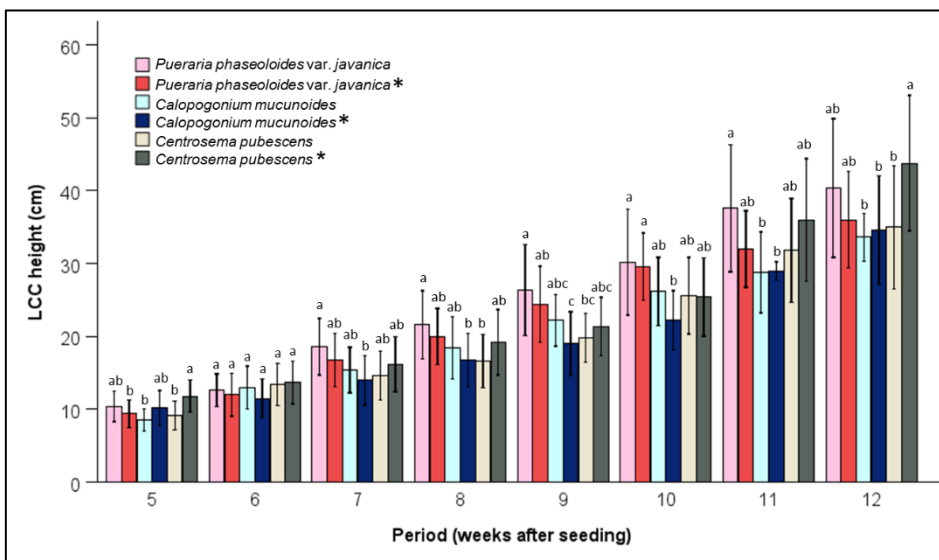


Figure 4: Leguminous cover crop height in cm in leguminous cover crop-*D. asper* integration; bar represents SE; * indicates nitrofoska application for *D. asper* starting from 10 weeks after leguminous cover crop seeding; means having similar letter within period are not significantly different at 5% level of significance.

Conversely, *C. pubescens* that had slower initial vine elongation gained benefit from fertilization of *D. asper* (*C. pubescens**); this leguminous cover crop showed positive upright growth response at 10 weeks after seeding, and had the greatest average height of 43.80 cm by the 12th week (Figure 4).

On the other hand, *C. mucunoides* was the leguminous cover crop species demonstrating the least height growth, regardless of fertilization for *D. asper* (*C. mucunoides* and *C. mucunoides**). Over time, this leguminous cover crop, however, also gained >30 cm in height by the 12th week (Figure 4).

Both the distinctive vine elongation rate and height

growth or thickness of the living mat offered by the different leguminous cover crop species affected their effectiveness in suppressing the growth of weeds under the unattended field conditions (Bakar, 2004; Dissanayaka et al., 2024; Gullickson, 2021; Samedani et al., 2015). During the initial month after leguminous cover crop seeding, there was leguminous cover crop-weed competition on the open land. Various grasses, sedges, and broadleaves developed profusely from the soil seed bank (Table 2) amidst germinating leguminous cover crop seeds, despite prior site clearance with the broad-spectrum herbicide of glyphosate-isopropylammonium. By the 5th week after leguminous cover crop seeding, the site generally still had a more than 90% weed cover rate (Figure 5). In the following month, *P. phaseoloides* and *C. pubescens*

having distinctive height or upright growth were more effective in reducing weed occurrence, compared to *C. mucunoides* (Figures 4-5). The thickness of the leguminous cover crop was crucial in hampering the germination and growth of weeds through a reduced light availability environment for the weeds, lowering the cost of herbicides in managing the plantations (Fernando and Shrestha, 2023; Rajakumar et al., 2025). In order to optimize the ground cover rates by leguminous cover crop, seeding with a mixture of leguminous cover crop species could be carried out. For example, *C. mucunoides* could be mixed with *P. phaseoloides* that had aggressive axillary growth and climbing habits. Likewise, *C. mucunoides* could also be mixed with *C. pubescens*, which also had height growth comparable to *P. phaseoloides*.

Despite the varied growth attributes, there was a general inverse association ($R^2 = 0.973$) between ground cover by leguminous cover crop and weed presence rates for all the leguminous cover crop species studied, indicating the overall benefits of these leguminous cover crop species in controlling weeds (Figure 5). The leguminous cover crop species generally exhibited approximately 40% ground coverage by the 12th week and suppressed the growth of most herbaceous weeds by this time. However, woody shrubs of *Solanum torvum* and *Tetracera scandens*, and volunteer *Elaeis guineensis* seedlings persisted among the leguminous cover crops. These woody shrubs were manually slashed after the 16th week. By the 24th week, the field generally had only approximately 10% weed presence, regardless of leguminous cover crop species or fertilization for *D. asper* (Figure 5).

Table 2: Weed species in the measurement plots at one month after leguminous cover crop seeding.

No.	Scientific name	Common name	Family	Relative frequency (%)
1	<i>Ageratum conyzoides</i>	Rumput tahi ayam	Asteraceae	3.5
2	<i>Asytasia gangetica</i>	Chinese violet	Acanthaceae	0.75
3	<i>Axonopus compressus</i>	Blanket grass	Poaceae	14
4	<i>Boerheria latifolia</i>	Broadleaf buttonweed	Angiospermae	10.25
5	<i>Cleome rutidosperma</i>	Fringed spiderflower	Cleomaceae	1.5
6	<i>Clidemia hirta</i>	Soapbush	Melastomataceae	1.5
7	<i>Cyperus compressus</i>	Annual sedge	Cyperaceae	0.75
8	<i>Cyperus difformis</i>	Variable flatsedge	Cyperaceae	0.75
9	<i>Cyperus kyllingia</i>	Whitehead spikesedge	Cyperaceae	1.5
10	<i>Cyperus rondotus</i>	Nut grass	Cyperaceae	10.5
11	<i>Digitaria ciliaris</i>	Southern crabgrass	Poaceae	0.75
12	<i>Elusine indica</i>	Rumput Sambu	Poaceae	13
13	<i>Lindernia dubia</i>	Yellowseed false pimpernel	Linderniaceae	4.25
14	<i>Ludwigia perrenis</i>	Perennial Water Primrose	Onagraceae	4.75
15	<i>Mimosa pudica</i>	Semalu	Fabaceae	0.5
16	<i>Paspalum conjugatum</i>	Rumput kerbau	Poaceae	2.25
17	<i>Paspalum scrobiculatum</i>	Kodo millet	Poaceae	0.25
18	<i>Simarouba glauca</i>	Paradise tree	Simaroubaceae	2.5
19	<i>Solanum torvum</i>	Terung Pipit	Solanaceae	5
20	<i>Tetracera scandens</i>	Akar mempelas putih	Dilleniaceae	21.5
21	<i>Elaeis guineensis</i>	Volunteer oil palm seedling	Arecaceae	0.25
Total				100

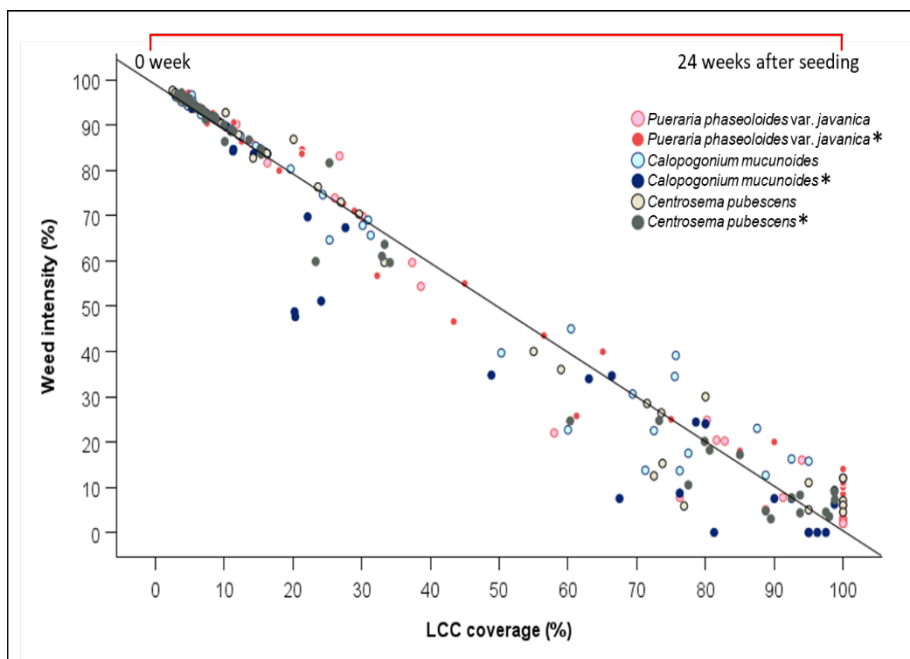


Figure 5: Weed intensity (%) in relation to leguminous cover crop ground cover (%) in leguminous cover crop-*D. asper* integration; * indicates nitrofoska application for *D. asper* starting from 10 weeks after leguminous cover crop seeding.

3.2 Growth of *D. asper*

With also sufficient rain during open field planting of *D. asper*, i.e., in the middle of March in 2023 or eight weeks after leguminous cover crop seeding (Figure 2), *D. asper* adapted well in the field and showed growth of new leaves within one month. By height, only control *D. asper* not integrated with leguminous cover crop and also not applied with nitrophoska fertilizer had significantly the least growth of height by one month after planting (Figure 6). In contrast, *D. asper* plots having 20-30% ground cover by the three different leguminous cover crop species, combined with nitrophoska fertilization for *D. asper* (*P. phaseoloides**, *C. mucunoides** and *C. pubescens**), and those not in companionship with

leguminous cover crop but received nitrophoska fertilization (Nitrophoska*) had significantly better plant height growth. In the subsequent month, the fertilized *D. asper* (*P. phaseoloides**, *C. mucunoides** and *C. pubescens**, Nitrophoska*) continued to show significant height increment compared to *D. asper* in plots not applied with fertilizer (Control, *P. phaseoloides*, *C. mucunoides*). Following lower rainfall and fewer rain days in June 2023, i.e., three months after *D. asper* planting, the plants did not gain much height growth (Figures 2 and 6). With higher rainfall in the 4th month, *D. asper* plants integrated with *C. pubescens* (*C. pubescens* and *C. pubescens**) generally demonstrated more height gain compared to plants integrated with *P. phaseoloides* alone (no nitrophoska fertilization).

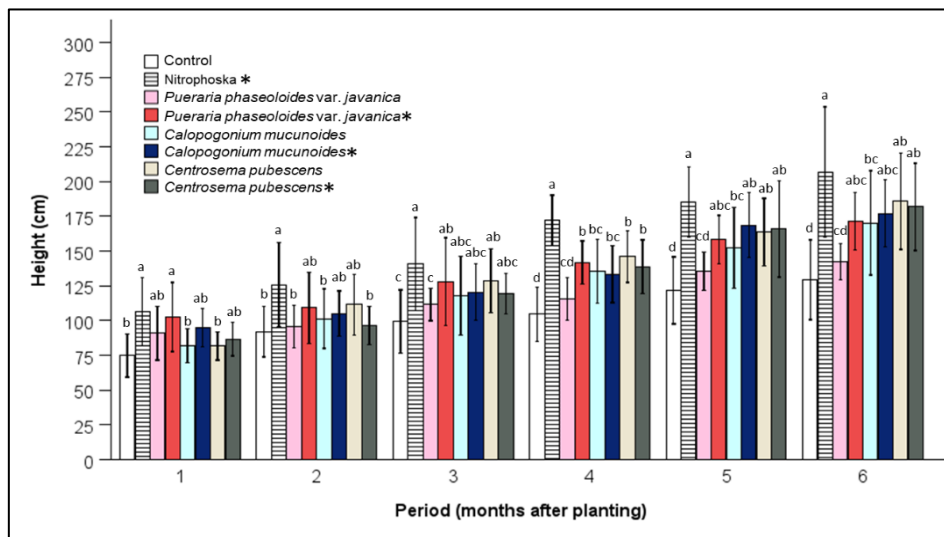


Figure 6: Height of *D. asper* in cm in leguminous cover crop-*D. asper* integration; bar represents SE; * indicates nitrophoska application for *D. asper* starting from 10 weeks after leguminous cover crop seeding; means having similar letter within period are not significantly different at 5% level of significance.

On the other hand, *D. asper* did not have any significant difference in the number of tillers per clump within the first three months after field planting, regardless of the different leguminous cover crop integrations or nitrophoska fertilization for *D. asper* (Figure 7). Later in the 4th to 6th month, non-fertilized *D. asper* plants gained benefits from integration with *C. pubescens*; the plants developed more new tillers compared to those subjected to other leguminous cover crop treatments. These plants had an average of 11.60 tillers per clump by the 6th month after field planting, being comparable to the nitrophoska-fertilized plants (Nitrophoska*) in tiller development. With a substantial ground cover, *C. pubescens* could have provided nutrients effectively to its companion crop of *D. asper* through atmospheric N fixation, in addition to soil conservation, and this could be beneficial in enhancing tiller development. At the same time, the thick living mulch offered by *C. pubescens* following a good ground cover rate suppressed weed growth, reducing competition for resources in *D. asper*. In other words, *C. pubescens*-*D. asper* could be fertilizer cost-saving. In contrast, control *D. asper* that was not

complemented by leguminous cover crop and received no fertilizer had significantly the fewest number of tillers (Figure 7).

The growth of *D. asper* was also described by its tiller diameter in this study. While *D. asper* plants receiving no nitrophoska fertilizer but integrated with *C. pubescens* also had superior tiller size in terms of tiller diameter, non-nitrophoska-fertilized *D. asper* in integration with *P. phaseoloides* or *C. mucunoides* also showed comparable tiller diameter, especially in the 5th and 6th month following almost full ground cover by the leguminous cover crops (Figures 5 and 8). The average tiller diameter of these *D. asper* plants was not significantly different from that of the nitrophoska-fertilized *D. asper*, proving again the benefits of leguminous cover crops in fertilizer cost-saving plantations (Figure 8). On the other hand, control *D. asper*, having no leguminous cover crop and no fertilizer, lacked soil conservation and had lower nutrition, and thus, the plants had significantly the smallest tillers by diameter.

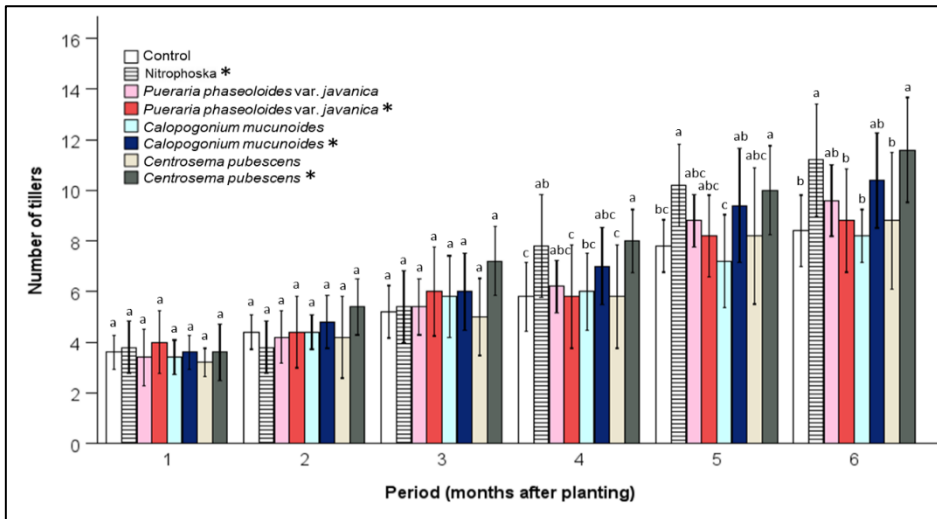


Figure 7: Number of tillers in *D. asper* clump in leguminous cover crop-*D. asper* integration; bar represents SE; * indicates nitrofoska application for *D. asper* starting from 10 weeks after leguminous cover crop seeding; means having similar letter within period are not significantly different at 5% level of significance.

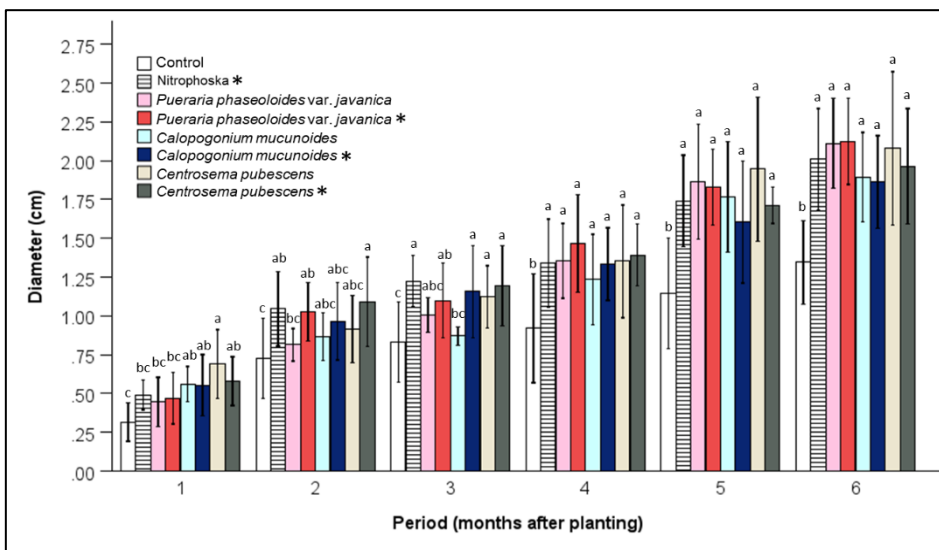


Figure 8: Diameter of *D. asper* tillers in cm in leguminous cover crop-*D. asper* integration; bar represents SE; * indicates nitrofoska application for *D. asper* starting from 10 weeks after leguminous cover crop seeding; means having similar letter within period are not significantly different at 5% level of significance.

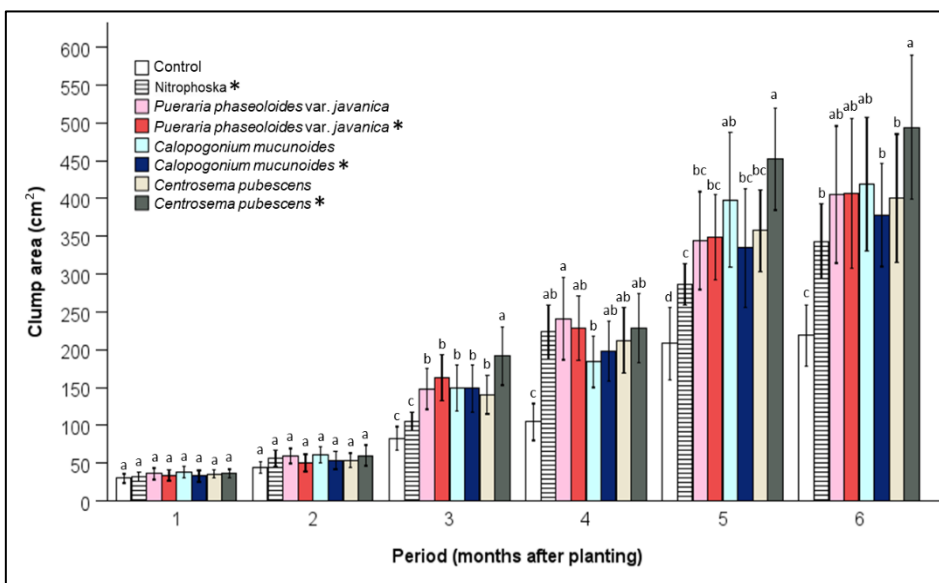


Figure 9: Clump area of *D. asper* in cm² in leguminous cover crop-*D. asper* integration; bar represents SE; * indicates nitrofoska application for *D. asper* starting from 10 weeks after leguminous cover crop seeding; means having similar letter within period are not significantly different at 5% level of significance.

The clump area, as another growth indicator, also proved a rather similar positive impact of leguminous cover crops on *D. asper*, notably when integrated with *C. pubescens* under no nitrophoska fertilization conditions (Figure 9). The *C. pubescens* complemented *D. asper* even developed significantly larger clump area compared to the nitrophoska-fertilized plants. Ultimately, *C. pubescens* contributed to the largest clump area of 494 cm² for *D. asper* by the 6th month (Figure 9). In addition to the above-mentioned soil conservation benefits following ground cover by this leguminous cover crop, other organic compounds, vitamins and hormonal substances from the organic matters could

Considering the varied influences of leguminous cover crops on *D. asper*, *C. pubescens* appeared as the best leguminous cover crop choice for *D. asper* silviculture, in which recurring patterns of enhanced tiller development, tiller diameter, and clump area were noted. The non-timber plants integrated with *C. pubescens* were superior to those supplemented by *P. phaseoloides* and *C. mucunoides*. Nonetheless, *C. pubescens* is a leguminous cover crop with slower initial growth and needs some external nutrition or fertilization to enable its earlier vine elongation and ground cover. Thus, mixing *C. pubescens* with other leguminous cover crop species, for example, *P. phaseoloides*, could express multiple benefits of rapid or earlier ground protection for smothering weeds, as well as soil conservation and nutrient recycling for sustainable *D. asper* production (Koehler-Cole et al., 2020). These insights not only enhance our understanding of leguminous cover crop as a supplement for *D. asper* but also offer practical and low-cost guidance for those who are involved in environmentally friendly management of *D. asper* plantations.

4. CONCLUSION

The findings of this study indicated that the choice and growth of leguminous cover crops could support the performance of *D. asper* differently in a sandy loam site. Notably, the data obtained consistently highlighted that *C. pubescens* was the most potent leguminous cover crop for enhancing the initial growth of *D. asper* without any fertilization after field planting. Alternatively, *P. phaseoloides*, which offered speedy initial ground cover, could be mixed with *C. pubescens* to support integration with *D. asper* for speedy soil conservation and nutrient improvement in a sustainable plantation of this non-timber crop. An extended observation period of up to a full production cycle of *D. asper* will further uncover the sustainability of leguminous cover crop-*D. asper* integration.

have also influenced the soil dweller populations, improving soil structures (Xaba et al., 2025). The positive impact of leguminous cover crop on soil health could have enabled a greater spread of new tillers emerging within a clump of *D. asper*, potentially enhancing the land cover by this non-timber crop and the ecological services of leguminous cover crop-*D. asper* over an extended time. On the other hand, the control *D. asper* that received no fertilizer and was not integrated with leguminous cover crop had only half the clump size ascribed by its smaller number of tillers and smaller tillers by diameter, as compared to those in companionship with leguminous cover crops.

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