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VIABILITY OF FORAGE SORGHUM INTEGRATION IN OIL PALM PLANTING AREA FOR PRODUCTION OF LIVESTOCK FODDER

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ABSTRACT

Forage sorghum has great potential to be integrated with oil palm as a fodder source for ruminant livestock. However, there was no study conducted on the suitability of forage sorghum cultivation in oil palm agriculture. Hence, the primary goals of this study were to investigate the suitability of several forage sorghum varieties integrated into the oil palm planting area and how they affect the oil palm yield. Five varieties of forage sorghum, i.e., *Superdan, Jumbo, Pacific BMR, Sugargraze and BMR Revolution obtained from Australia were used in this study. The field trials were carried out at five locations,* i.e., *Malaysian Palm Oil Board (MPOB) Kluang Research Station, MPOB Keratong Research Station, MPOB Teluk Intan Research Station, MPOB Lahad Datu Research Station and Ladang MAAH KLIA. The trials were laid down in a randomised complete block design (RCBD). Each plot was 7 m × 4 m (28 m^2) in size with four replicates (20 plots). Seeds were manually dibbled into 70 cm × 20 cm bands. One planting season of forage sorghum took almost six months to complete with four harvesting rounds. Two rounds of planting can be carried out in one year depending on the climatic condition. Results of the study indicated that forage sorghum grew well in the double avenue oil palm planting area. Sugargraze variety produced the highest fresh and dry fodder weight at all trial locations except MPOB/MAAH plantation. It was followed by BMR Revolution as the second highest fodder producer. The highest estimated dry fodder yield was 18.23 t ha^{-1} season^{-1} for Sugargraze variety and 12.97 t ha^{-1} season^{-1} for BMR Revolution. In terms of nutritional values, total digestible nutrient (TDN) values ranged from 57.00%-63.93% for all five varieties. This study also revealed that forage sorghum planting in the double avenue oil palm planting area did not affect the oil palm yield. The gross and net revenue of fresh fodder production were RM18 840 ha^{-1} and RM7680 ha^{-1}, respectively. A total monthly income of RM1317 ha^{-1} can be generated by forage sorghum and oil palm integration. Thus, the integration of forage sorghum in the double avenue oil palm planting area is technically and economically viable for adoption to optimise land use, diversify the income stream of oil palm growers and lend support to ensure the sustainability of Malaysia's livestock industry.*

Keywords: double-avenue, forage sorghum, oil palm crop integration.

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INTRODUCTION

Sorghum, *Sorghum vulgare* originated from East Central Africa, in Ethiopia and Sudan. It was introduced into Malaysia in 1969 and has been cultivated at the Agriculture Station, Sungai Udang, Melaka, Malaysia during the paddy off-season. It belongs to the family *Poaceae* similar to wheat, rice and maize. It can grow up to 0.5 to 4.0 m high. Sorghum grows well in a warm climate with temperatures ranging from 26°C to 37°C. It can be grown at as high as 1200 m above sea level. It can tolerate high temperatures, drought conditions and intermittent waterlogging.

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Sorghum has shown great potential to supplement fodder resources in India (Reddy, 2017). It was extensively cultivated in the Americas and Australia primarily for animal feed (Taylor, 2019). It is a fast-growing, tasty, and nutritious fodder that may be used as silage and hay in addition to fresh feeding (Singh *et al.*, 2016). Forage sorghum performs best on heavier soils due to its greater moisture holding capacity and natural fertility. Although forage sorghum has good drought tolerance and can be sown on lighter soils, productivity may be reduced unless adequate fertilising is carried out and suitable varieties are being used. It has a reputation for producing fast and large quantities of livestock feed. It can be grazed or turned into silage or hay. Under the average condition, it can produce 4 t ha^{-1} of DM within 50 days of planting. An irrigated study in New Mexico discovered that Brown Mid Rib (BMR) forage sorghum produced 21.1 t ha^{-1} of DM when harvested at the soft dough stage (Lyons *et al.*, 2019). It has great potential to be integrated with oil palm as a fodder source because of its wide adaptation, rapid growth, high green, and dry fodder yields.

Annually, Malaysia is importing feed for livestock and ruminant worth about RM3 billion. Feed import quantity and value are expected to increase significantly in the future due to an increase in demand and price. Thus, it is crucial to minimise dependencies on imported fodder by introducing new livestock feeds which are competitive for the livestock industry in Malaysia. Forage sorghum integration with oil palm has the potential to be the alternative feed for livestock production. Three years of observation on the forage sorghum planting indicated that it adapted well to Malaysian soil and climatic conditions. In line with that, it has a great potential to be planted large-scale under an integration system with oil palm specifically for forage production for the livestock industry. Therefore, there is an urgent need to adopt and conduct a thorough study that includes comprehensive data, especially on the suitability of forage sorghum integration with oil palm for forage production.

MATERIALS AND METHODS

Study Sites

Trials on forage sorghum integration with oil palm were carried out at five MPOB research plots. They were Ladang Malaysian Agriculture and Horticulture (MAAH) KLIA, Selangor (2°46′44″ N 101°40″26″ E); MPOB Research Station in Kluang, Johor (1°57′23″ N 103°22′19″ E); MPOB Research Station in Keratong, Pahang (2°46′42″ N 103°55′18″ E); MPOB Research Station in Lahad Datu, Sabah (5°01′46″ N 118°25′01″ E) and MPOB Research Station in Teluk Intan, Perak (3°49′05″ N 118°58′58″ E). This experiment was carried out for five years.

Oil Palm Planting System

Oil palm was planted following the double avenue oil palm planting system. The average age of the oil palms at the start of this study was six years old. The palms were planted at 6.1 m within the same row and 9.1 m between the rows, while the vacant space between the two oil palm rows was 15.2 m (*Figure 1*). The palm density was 136 palms ha^{-1}, similar to the conventional triangular oil palm planting system with a planting distance of 9.1 m × 9.1 m × 9.1 m. The 15.2 m vacant area of double avenue oil palm planting was cleared of bushes and debris from the previous crop. This area was used for trials on forage sorghum planting.

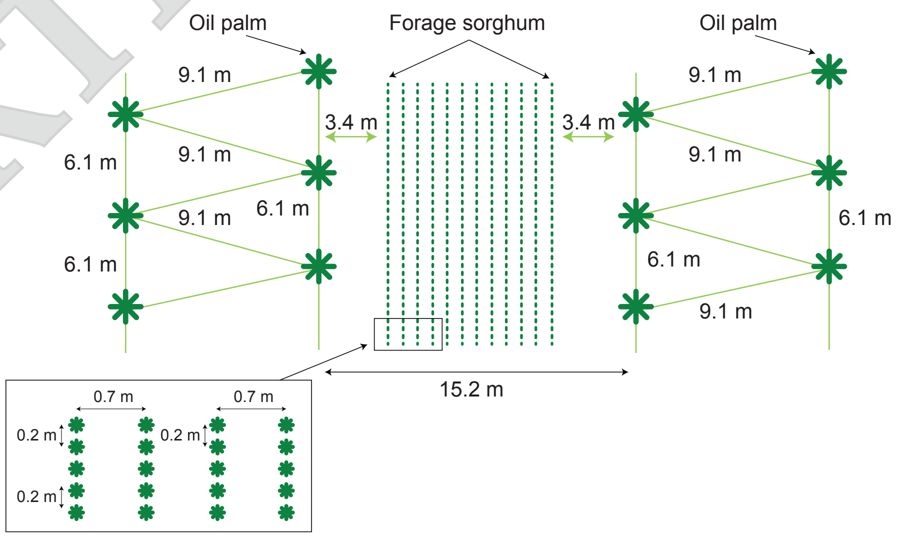

Figure 1. Layout of forage sorghum integration in double-avenue oil palm planting area.

Experimental Plot and Design

Field trials were conducted to compare the performance of several forage sorghum varieties integrated into the oil palm planting area. The forage sorghum seeds used in this study were obtained from two companies in Australia, *i.e.*, Pacific Seeds Pty. Ltd. and Heritage Seeds Pty. Ltd. In this study, five varieties of forage sorghum were tested in the field using a randomised complete block design (RCBD) with four replications. The plot size was 7 m × 4 m (28 m^2) with a total of 20 plots. The treatments were assigned at random to the experimental units or plots (*Table 1*). All agricultural practices were the same at five different locations of the study.

Land preparation. The experimental plots were subjected to three rounds of ploughing, *i.e.*, two rounds of disc ploughing and one round of rotor tilling. Ground Magnesium Limestone (GML) was applied to each plot at the rate of one tonne per hectare, three weeks before seeds planting.

Seed planting. The seeds were manually dibbled into a 70 cm × 20 cm band. The seeds can also be planted using a seeder machine. The Alachlor herbicide was sprayed at 2.0 kg ha^{-1} after seeds sowing to control pre-emergence weeds in the plots. Manual weeding was carried out a month after planting. Three rounds of the weeding programme were conducted for one planting season. It was conducted at an interval of 10-14 days after each harvesting programme. Generally, four rounds of harvesting can be conducted for one planting season.

Fertiliser application. The types of fertiliser and rates used are shown in *Table 2*. The fertilisers were hand broadcasted and raked evenly into related plots as basal dressing before seed planting. Basal fertilisers were broadcasted in the plots before the final rotor tilling to ensure that fertilisers were evenly incorporated into the soil. Row dressing was applied as the top dressing after every harvest or cutting to promote forage sorghum re-growth from its stubble or stump. The top dressing was conducted on day three after the first, second and third harvesting programmes.

Pest and disease control. Generally, there are no major or severe pests and diseases reported for forage sorghum cultivation. Pest control was conducted based on incidence by applying insecticides such as dimethoate, carbaryl, trichlorphon and deltamethrin. The rat problem was controlled by using rat baits containing flocoumafen 0.005% w/w which were placed in the Ecorat (plastic container). The incidence of diseases was controlled by spraying fungicides such as Benomyl and Thiram.

Vegetative Measurement

Vegetative measurements of forage sorghum such as the plant height and the number of leaves were collected at each harvesting round and were carried out 40 to 45 days after each harvesting programme. Data were collected from the first to fourth harvesting programmes.

Dry Matter (DM) Estimation

DM is referred to as the portion of forage material that remained after its moisture is extracted. All animal feed requirements are calculated on a dry matter basis. DM content is measured by drying the samples in an oven at 100°C and is expressed as a percentage. The plants were sampled using the quadrant square (1 m × 1 m) and they were collected from all the treatments. Each sample was made-up of five plants. The plant parts were separated into leaflets and stem before they were dried in the oven. The above-ground sorghum's biomass (wet and dry) was estimated by multiplying the average wet and dry weight of sampled plants with the total number of sorghum plants per hectare (71 428 plants).

Forage Sorghum Nutritional Values

The nutritional value of forage is defined as its ability to support a certain level of animal performance. The nutrient or chemical composition

TABLE 1. ARRANGEMENT OF THE TREATMENTS IN THE FIELD

Replicate 1	Replicate 2	Replicate 3	Replicate 4
Superdan	Pacific BMR	BMR Revolution	Jumbo
Jumbo	BMR Revolution	Jumbo	BMR Revolution
Pacific BMR	Superdan	Sugar graze	Superdan
Sugar graze	Jumbo	Pacific BMR	Pacific BMR
BMR Revolution	Sugar graze	Superdan	Sugar graze

Note: BMR - Brown Mid Rib.

TABLE 2. FERTILISER PROGRAMME FOR FORAGE SORGHUM INTEGRATION IN OIL PALM PLANTING AREA

Types of fertiliser	Basal dressing (kg ha^{-1})	Top dressing (kg ha^{-1})
Nitrophoska 15:15:15	500	
Triple super phosphate	98	
Muriate of potash	75	
Urea		163

of forage largely determines its quality. The quality of the forage is determined by plant characteristics, harvesting and storage methods. Three plants were randomly sampled from each treatment plot. The plants were weighed and then dried in an oven at a temperature of 60°C for 24 hr. The samples were sent to the Department of Veterinary and Services for nutritional analysis. The analysis was carried out for DM, crude protein (CP), metabolisable energy (ME), total digestible nutrient (TDN), crude fibre (CF), neutral detergent fibre (NDF) and acid detergent fibre (ADF). The analysis was carried out using Malaysian Standard Methods of Test for Animal Feedstuffs, First Revision, 1982, (Goering and Soest, 1970; Menke *et al*., 1975).

Fresh Fruit Bunch (FFB) Yield Recording at Ladang MAAH, KLIA

The FFB yield of 16 recording palms in all trial plots at Ladang MAAH, KLIA were recorded at every harvesting round of two weeks interval. The data was recorded for five years harvests.

Statistical Analysis

The effects of various treatments on forage sorghum growths, nutrients uptake, and physiological parameters were subjected to analysis of variance (ANOVA) and the means were compared using Duncan Multiple Range Test (DMRT) by SAS version 9.3. Unless otherwise stated, statistical significance refers to the 0.05 probability level (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Data of the field trials on five forage sorghum varieties integration in oil palm planting areas conducted at Ladang MAAH, KLIA and four MPOB Research Stations were analysed using Statistical Analysis System, SAS version 9.3. Results of the data analysis are as shown in *Tables 3-12*. The results are an average of four harvests from the main crop and three ratoon crops for each location of the trial except for the MPOB Research Station in Keratong, Pahang. In Keratong, the data were recorded for three harvests only due to a severe drought season during the experiment.

Vegetative Growth and Yield Production

MPOB Research Station in Keratong, Pahang. ANOVA for vegetative growth and fodder yield of forage sorghum planting at MPOB Research Station in Keratong, Pahang is presented in *Table 3*. The results indicated that the means of treatment were not significantly different at p<0.05. *Table 4* shows the treatments that were not significantly different at p<0.05. The results showed that the Jumbo variety had the highest number of leaves (mean=7.8) and plant height (mean=97.9 cm) but were not significantly different compared to other varieties.

Jumbo variety produced higher fresh fodder weight (mean=36.53 g plant^{-1}) and dry fodder weight (mean=9.74 g plant^{-1}) compared to other varieties. The results indicated that the Jumbo variety produced the highest fodder yield

TABLE 3. ANOVA FOR VEGETATIVE GROWTH AND FODDER YIELD AT MPOB RESEARCH STATION IN KERATONG

Source	df	Number of leaves	Height (cm)	Fresh weight of leaves (g plant^{-1})	Dry weight of leaves (g plant^{-1})	Fresh weight of stem (g plant^{-1})	Dry weight of stem (g plant^{-1})	Total fresh weight (g plant^{-1})	Total dry weight (g plant^{-1})
Replicate	3	14.70 **	1 395.23 ^{ns}	15 865.37 ^{ns}	19.15 ^{ns}	1 485.09 **	122.74 **	2 973.33 **	232.10 **
Treatment	4	10.12 ^{ns}	1 697.15 ^{ns}	13 236.01 ^{ns}	11.74 ^{ns}	141.24 ^{ns}	19.54 ^{ns}	411.24 ^{ns}	52.01 ^{ns}

Note: Figure are means of treatment; ns - not significant; ** - significant at 5% level (Duncan Multiple Range Test).

TABLE 4. EFFECT OF TREATMENTS ON VEGETATIVE GROWTH AND FODDER YIELD AT MPOB RESEARCH STATION IN KERATONG

Treatment	Number of leaves	Height (cm)	Fresh weight of leaves (g plant^{-1})	Dry weight of leaves (g plant^{-1})	Fresh weight of stem (g plant^{-1})	Dry weight of stem (g plant^{-1})	Total fresh weight (g plant^{-1})	Total dry weight (g plant^{-1})
Superdan	7.26 ^{b}	89.43 ^{a}	11.78 ^{a}	3.30 ^{a}	17.96 ^{a}	3.83 ^{a}	29.83 ^{a}	7.13 ^{a}
Jumbo	7.83 ^{ab}	97.95 ^{a}	15.48 ^{a}	4.41 ^{a}	21.55 ^{a}	5.33 ^{a}	36.53 ^{a}	9.74 ^{a}
Pacific BMR	8.21 ^{a}	94.33 ^{a}	13.69 ^{a}	3.72 ^{a}	18.51 ^{a}	4.67 ^{a}	32.20 ^{a}	8.40 ^{a}
Sugargraze	7.15 ^{b}	86.43 ^{a}	12.55 ^{a}	3.34 ^{a}	18.19 ^{a}	4.98 ^{a}	30.91 ^{a}	8.33 ^{a}
BMR Revolution	7.42 ^{ab}	98.29 ^{a}	13.85 ^{a}	3.73 ^{a}	19.51 ^{a}	4.48 ^{a}	33.37 ^{a}	8.21 ^{a}
Coefficient of variation (%)	27.97	34.84	81.03	75.08	113.88	138.60	98.17	107.28

Note: Mean in the same column with similar alphabet are not significantly different at p<0.05 (Duncan Multiple Range Test).

(*Figure 2*). Jumbo produced the highest total dry weight compared to other varieties, *i.e.*, Superdan (by 26.7%), BMR Revolution (by 15.8%), Sugargraze (by 14.5%) and Pacific BMR (by 13.8%). Jumbo variety showed the highest in vegetative growth and plant DM production but not significantly different compared to other forage sorghum varieties.

Ladang MAAH, KLIA. ANOVA in *Table 5* indicates that the means of totally fresh and DM weight were significantly different at $p<0.05$ for forage sorghum planting at Ladang MAAH, KLIA. Results in *Table 6* show that the Pacific BMR variety had the highest number of leaves (mean=12.5) and the Jumbo variety had the highest plant height (mean=97.9 cm) but not significantly different compared to other varieties except for Pacific BMR.

BMR Revolution variety produced significantly higher fresh fodder weight (mean=168.12 g plant^{-1}) and total dry fodder weight (mean=28.886 g plant^{-1}) compared to other varieties except for Jumbo, Pacific BMR and Sugargraze. The results indicated that the BMR revolution produced the highest total dry weight compared to other varieties, *i.e.*, Superdan (by 21.3%), Pacific BMR (by 15.9%), Jumbo (by 12.9%) and Sugargraze (by 4.3%). BMR Revolution variety (*Figure 3*) showed the highest in vegetative growth and plant DM production but not significantly different compared to other forage sorghum varieties.

MPOB Research Station in Kluang, Johor. ANOVA in *Table 7* indicates that the means of several treatments were significantly different at $p<0.05$. Results in *Table 8* indicated no significant difference in the number of leaves for all tested varieties. However, the Jumbo variety recorded significantly higher plant height (mean=151.7 cm) compared to other varieties except for Superdan and BMR Revolution.

(a)

(b)


Figure 2. Jumbo variety at (a) 25 days after planting and (b) 20 days after the second harvest at MPOB Research Station in Keratong, Pahang.

TABLE 5. ANOVA FOR VEGETATIVE GROWTH AND FODDER YIELD AT LADANG MAAH, KLIA

Source	df	Number of leaves	Height (cm)	Fresh weight of leaves (g plant^{-1})	Dry weight of leaves (g plant^{-1})	Fresh weight of stem (g plant^{-1})	Dry weight of stem (g plant^{-1})	Total fresh weight (g plant^{-1})	Total dry weight (g plant^{-1})
Replicate	3	176.58 **	25 597.51 ***	568.23 ns	15.68 ns	24 355.34 **	656.75 **	32 313.74 ***	844.81 **
Treatment	4	43.43 **	7 146.09 **	1 820.59 **	69.74 **	7 321.40 ns	467.83 **	6 767.38 ns	243.23 ns

Note: Figure is means of treatment; ns - not significant; ** - significant at 5% level (Duncan Multiple Range Test).

TABLE 6. EFFECT OF TREATMENTS ON VEGETATIVE GROWTH AND FODDER YIELD AT LADANG MAAH, KLIA

Treatment	Number of leaves	Height (cm)	Fresh weight of leaves (g plant^{-1})	Dry weight of leaves (g plant^{-1})	Fresh weight of stem (g plant^{-1})	Dry weight of stem (g plant^{-1})	Total fresh weight (g plant^{-1})	Total dry weight (g plant^{-1})
Superdan	11.54 ab	103.63 a	57.95 ab	11.02 a	89.98 b	11.87 c	147.93 a	22.73 b
Jumbo	12.31 ab	115.16 a	59.12 a	11.04 a	94.96 b	14.33 bc	154.09 a	25.17 ab
Pacific BMR	12.58 a	92.77 b	53.98 ab	10.49 ab	91.29 b	15.94 bc	142.24 a	24.28 ab
Sugargraze	10.38 b	113.82 a	56.97 ab	10.70 a	106.97 ab	18.13 ab	162.16 a	27.63 a
BMR Revolution	11.94 ab	110.42 a	48.59 b	8.78 b	119.54 a	22.48 a	168.12 a	28.89 a
Coefficient of variation (%)	48.5097	29.04	49.20	49.32	56.37	62.46	48.46	50.48

Note: Mean in the same column with similar alphabet are not significantly different at $p<0.05$ (Duncan Multiple Range Test).

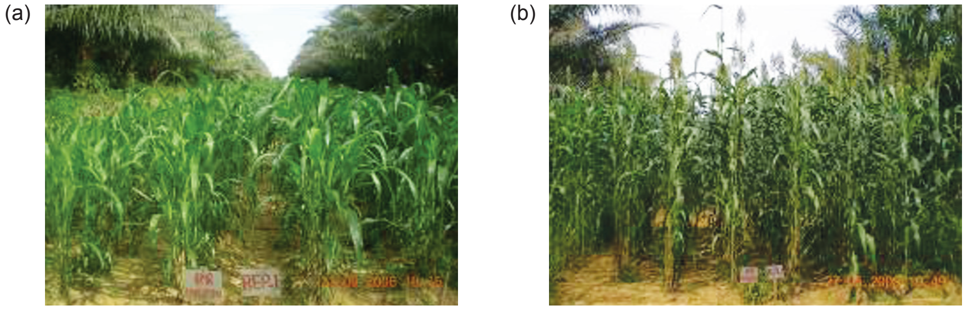

Figure 3. BMR Revolution variety at (a) 25 days and (b) 60 days after planting at Ladang MAAH, KLIA.

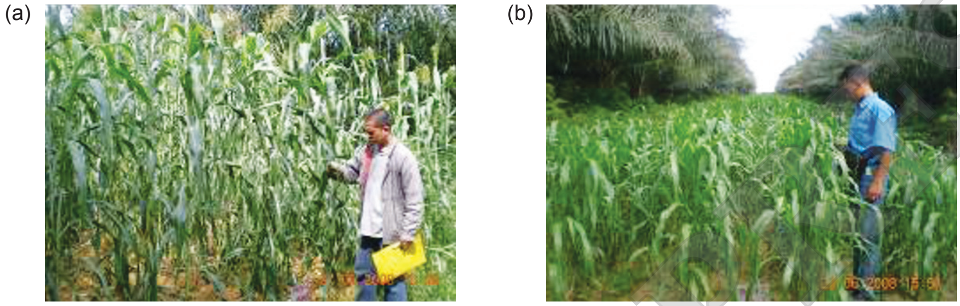

Figure 4. Pacific BMR variety at (a) 60 days after planting and (b) 25 days after the first harvest at Ladang MAAH, KLIA.

The BMR Revolution variety produced a significantly higher fresh weight of leaves (mean=53.7 g plant^{-1}) and dry weight of leaves (mean=11.7 g plant^{-1}) compared to other varieties except for Sugargraze. However, Sugargraze variety recorded significantly higher fresh weight of stem (mean=174.1 g plant^{-1}), dry weight of stem (mean=27.9 g plant^{-1}) and total dry weight (mean=38.9 g plant^{-1}) (*Table 8*). The results indicated that Sugargraze variety produced the highest total dry weight compared to other varieties, *i.e.*, BMR Revolution (by 24.3%), Pacific BMR (by 34.7%), Jumbo (by 35.9%) and Superdan (by 43.2%). The results showed that Sugargraze (*Figure 5*) was the best forage sorghum variety in terms of vegetative growth and plant DM production and followed by BMR Revolution and Pacific BMR and Jumbo.

TABLE 7. ANOVA FOR VEGETATIVE GROWTH AND FODDER YIELD AT MPOB RESEARCH STATION IN KLUANG, JOHOR

Source	df	Number of leaves	Height (cm)	Fresh weight of leaves (g plant^{-1})	Dry weight of leaves (g plant^{-1})	Fresh weight of stem (g plant^{-1})	Dry weight of stem (g plant^{-1})	Total fresh weight (g plant^{-1})	Total dry weight (g plant^{-1})
Replicate	3	4.75 **	2 901.94 **	1 514.05 **	24.56 **	7 989.48 **	30.04 ^{ns}	1 024 165.48 ^{ns}	54.95 ^{ns}
Treatment	4	0.94 ^{ns}	434.47 **	2 010.38 **	91.89 **	67 151.49 **	2 317.95 **	1 148 168.99 ^{ns}	2878.81 **

Note: Figure is means of treatment; ns - not significant; ** - significant at 5% level (Duncan's Multiple Range Test).

TABLE 8. EFFECT OF TREATMENTS ON VEGETATIVE GROWTH AND FODDER YIELD AT MPOB RESEARCH STATION IN KLUANG, JOHOR

Treatment	Number of leaves	Height (cm)	Fresh weight of leaves (g plant^{-1})	Dry weight of leaves (g plant^{-1})	Fresh weight of stem (g plant^{-1})	Dry weight of stem (g plant^{-1})	Total fresh weight (g plant^{-1})	Total dry weight (g plant^{-1})
Superdan	9.55 ^{a}	147.98 ^{ab}	41.34 ^{c}	9.20 ^{b}	95.37 ^{c}	17.81 ^{b}	136.82 ^{c}	22.15 ^{d}
Jumbo	9.41 ^{a}	151.79 ^{a}	41.78 ^{c}	9.18 ^{b}	105.01 ^{bc}	15.80 ^{b}	147.12 ^{c}	24.98 ^{c}
Pacific BMR	9.38 ^{a}	145.93 ^{b}	46.74 ^{b}	9.89 ^{b}	103.25 ^{bc}	15.54 ^{b}	149.97 ^{c}	25.44 ^{c}
Sugargraze	9.41 ^{a}	147.53 ^{b}	48.73 ^{b}	11.03 ^{a}	174.13 ^{a}	27.96 ^{a}	222.85 ^{a}	38.99 ^{a}
BMR Revolution	9.33 ^{a}	149.18 ^{ab}	53.72 ^{a}	11.71 ^{a}	113.85 ^{b}	17.81 ^{b}	167.88 ^{b}	29.52 ^{b}
Coefficient of variation (%)	10.44	8.37	32.63	25.68	35.34	39.41	39.41	31.64

Note: Mean in the same column with similar alphabet are not significantly different at p<0.05 (Duncan's Multiple Range Test).

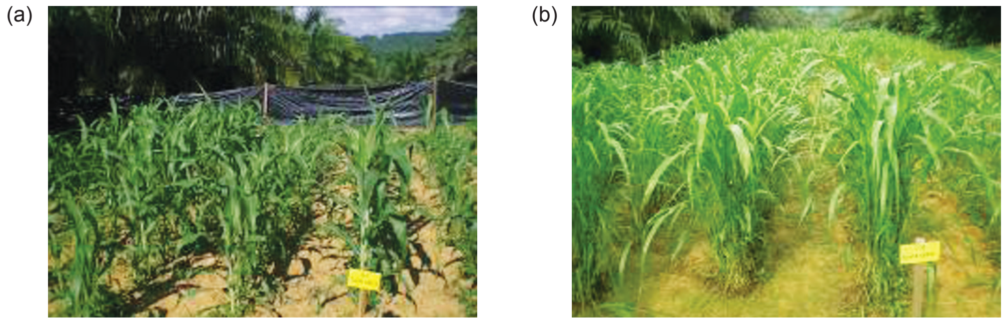

Figure 5. Sugargraze variety at (a) 20 days after planting and (b) 25 days after the second harvest at MPOB Research Station in Kluang, Johor.

MPOB Research Station in Lahad Datu, Sabah. ANOVA in *Table 9* indicates that the means of treatment were significantly different at $p<0.05$ except for the fresh weight of leaves. *Table 10* indicates that the Pacific BMR variety recorded a significantly higher number of leaves (mean=10.8) compared to other varieties. Meanwhile, the Jumbo variety recorded significantly higher plant height (mean=214.7 cm) compared to other varieties except for Sugargraze.

The results indicated no significant difference in the fresh weight of leaves for all tested sorghum varieties. Sugargraze produced a significantly higher dry weight of leaves (mean=12.2 g plant^{-1}), fresh weight of stem (mean=297.5 g plant^{-1}), dry weight of stem (mean=51.5 g plant^{-1}), total fresh weight (mean=353.3 g plant^{-1}) and total dry weight (mean=63.7 g plant^{-1}) (*Table 10*). The results indicated that Sugargraze variety produced the highest total dry weight compared to other varieties, *i.e.*, BMR Revolution (by 28.9%), Pacific BMR (by 32.9%), Jumbo (by 36.0%) and Superdan (by 52.4%). The results showed that Sugargraze (*Figure 6*) is the best forage sorghum variety in terms of vegetative growth and plant DM production and followed by BMR Revolution and Pacific BMR and Jumbo.

MPOB Research Station in Teluk Intan, Perak. ANOVA in *Table 11* indicates that the means of treatment were significantly different at $p<0.05$. *Table 12* indicates that the Pacific BMR variety recorded a significantly higher number of leaves (mean=7.8) compared to other varieties except for BMR Revolution and Jumbo. Meanwhile, the Jumbo variety recorded significantly higher plant height (mean=145.8 cm) compared to other varieties.

The results indicated that Sugargraze produced a significantly higher fresh weight of leaves (mean=54.9 g plant^{-1}), dry weight of leaves (mean=9.8 g plant^{-1}), fresh weight of stem (mean=164.3 g plant^{-1}), dry weight of stem

TABLE 9. ANOVA FOR VEGETATIVE GROWTH AND FODDER YIELD AT MPOB RESEARCH STATION IN LAHAD DATU, SABAH

Source	df	Number of leaves	Height (cm)	Fresh weight of leaves (g plant^{-1})	Dry weight of leaves (g plant^{-1})	Fresh weight of stem (g plant^{-1})	Dry weight of stem (g plant^{-1})	Total fresh weight (g plant^{-1})	Total dry weight (g plant^{-1})
Replicate	3	2.61 ^{ns}	6 423.82 **	43 791.67 ^{ns}	33.89 ^{ns}	21 393.27 ^{ns}	306.31 ^{ns}	49 681.06 ^{ns}	500.94 ^{ns}
Treatment	4	318.14 **	53 188.134 **	51 260.067 ^{ns}	979.94 **	1 247 193.57 **	42 405.34 **	15 646.21 ***	55 729.79 **

Note: Figure is means of treatment; ns - not significant; ** - significant at 5% level (Duncan Multiple Range Test).

TABLE 10. EFFECT OF TREATMENTS ON VEGETATIVE GROWTH AND FODDER YIELD AT MPOB RESEARCH STATION IN LAHAD DATU, SABAH

Treatment	Number of leaves	Height (cm)	Fresh weight of leaves (g plant^{-1})	Dry weight of leaves (g plant^{-1})	Fresh weight of stem (g plant^{-1})	Dry weight of stem (g plant^{-1})	Total fresh weight (g plant^{-1})	Total dry weight (g plant^{-1})
Superdan	9.656 ^{c}	192.61 ^{c}	34.63 ^{d}	7.94 ^{d}	145.21 ^{c}	22.746 ^{d}	179.84 ^{c}	30.38 ^{d}
Jumbo	10.12 ^{b}	214.78 ^{a}	42.75 ^{c}	9.49 ^{c}	192.28 ^{b}	31.19 ^{c}	257.72 ^{b}	40.83 ^{c}
Pacific BMR	10.80 ^{a}	187.57 ^{d}	46.09 ^{b}	10.03 ^{bc}	191.47 ^{b}	32.73 ^{bc}	236.86 ^{b}	42.76 ^{bc}
Sugargraze	8.33 ^{d}	211.73 ^{a}	55.79 ^{a}	12.29 ^{a}	297.59 ^{a}	51.54 ^{a}	353.38 ^{a}	63.79 ^{a}
BMR Revolution	9.48 ^{c}	201.84 ^{b}	46.83 ^{b}	10.65 ^{b}	181.78 ^{b}	34.73 ^{b}	228.48 ^{b}	45.39 ^{b}
Coefficient of variation (%)	32.27	16.91	45.06	46.04	63.45	51.29	97.31	46.04

Note: Mean in the same column with similar alphabet are not significantly different at $p<0.05$ (Duncan Multiple Range Test).

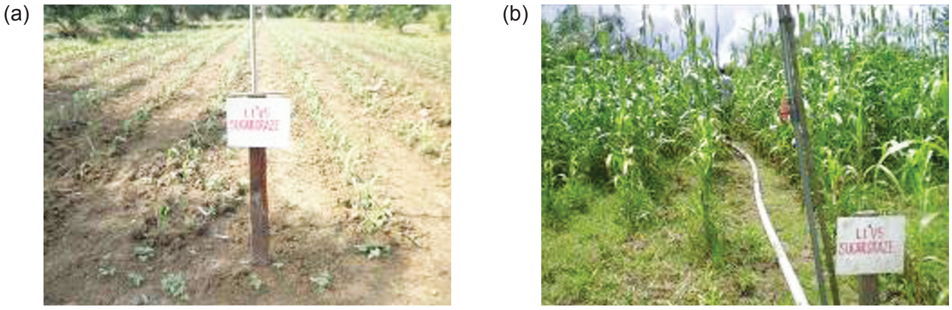

Figure 6. Sugargraze variety at (a) 7 days and (b) 60 days after planting at MPOB Research Station in Lahad Datu, Sabah.

(mean=16.3 g plant^{-1}), total fresh weight (mean=219.3 g plant^{-1}) and total dry weight (mean=26.2 g plant^{-1}) (*Table 12*). The results indicated that Sugargraze variety produced the highest total dry weight compared to other varieties, *i.e.*, BMR Revolution (by 28.6%), Jumbo (by 29.0%), Pacific BMR (by 38.6%) and Superdan (by 54.4%). The results showed that Sugargraze (*Figure 7*) is the best forage sorghum variety in terms of vegetative growth and plant DM production and followed by BMR Revolution and Jumbo and Pacific BMR.

Estimation of Forage Sorghum Production

Table 13 shows the estimated fresh and DM weight of forage sorghum production for one

TABLE 11. ANALYSIS OF VARIAN FOR VEGETATIVE GROWTH AND FODDER YIELD AT MPOB RESEARCH STATION IN TELUK INTAN, PERAK

Source	df	Number of leaves	Height (cm)	Fresh weight of leaves (g plant^{-1})	Dry weight of leaves (g plant^{-1})	Fresh weight of stem (g plant^{-1})	Dry weight of stem (g plant^{-1})	Total fresh weight (g plant^{-1})	Total dry weight (g plant^{-1})
Replicate	3	18.12 **	25 641.44 **	683.7270 **	23.6527 **	27 612.75 **	323.343 **	35 396.527 **	509.79 **
Treatment	4	15.86 **	11 202.41 **	7 424.67**	245.00 **	121 842.97 **	1 022.72 **	182 729.20 **	2 193.74 **

Note: Figure is means of treatment; ns - not significant; ** - significant at 5% level (Duncan Multiple Range Test).

TABLE 12. EFFECT OF TREATMENTS ON VEGETATIVE GROWTH AND FODDER YIELD AT MPOB RESEARCH STATION IN TELUK INTAN, PERAK

Treatment	Number of leaves	Height (cm)	Fresh weight of leaves (g plant^{-1})	Dry weight of leaves (g plant^{-1})	Fresh weight of stem (g plant^{-1})	Dry weight of stem (g plant^{-1})	Total fresh weight (g plant^{-1})	Total dry weight (g plant^{-1})
Superdan	6.91 ^{b}	122.05 ^{c}	28.94 ^{c}	5.09 ^{d}	64.77 ^{d}	6.89 ^{d}	93.71 ^{c}	11.98 ^{d}
Jumbo	7.68 ^{a}	145.89 ^{a}	37.67 ^{b}	7.19 ^{c}	93.79 ^{b}	11.43 ^{b}	131.46 ^{b}	18.62 ^{b}
Pacific BMR	7.85 ^{a}	115.21 ^{c}	41.79 ^{b}	7.25 ^{c}	77.75 ^{cd}	8.85 ^{c}	119.54 ^{b}	16.10 ^{c}
Sugargraze	7.03 ^{b}	135.41 ^{b}	54.99 ^{a}	9.84 ^{a}	164.39 ^{a}	16.39 ^{a}	219.38 ^{a}	26.23 ^{a}
BMR Revolution	7.73 ^{a}	130.537 ^{b}	42.76 ^{b}	8.09 ^{b}	87.32 ^{bc}	10.63 ^{b}	130.08 ^{b}	18.72 ^{b}
Coefficient of variation (%)	15.36	18.83	37.81	35.05	45.28	46.68	40.87	39.21

Note: Mean in the same column with similar alphabet are not significantly different at $p<0.05$ (Duncan Multiple Range Test).

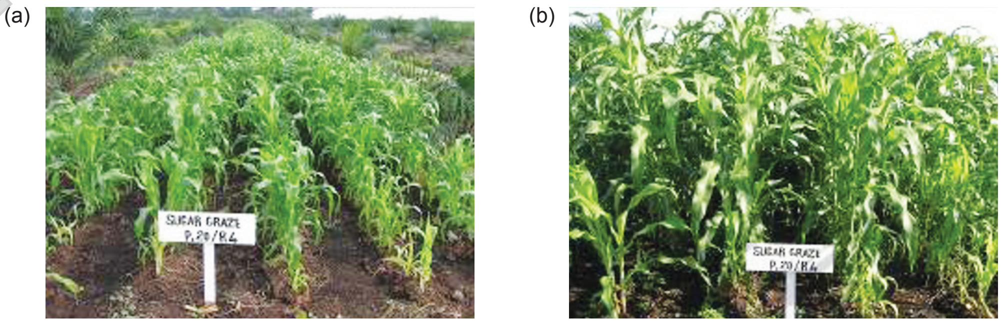

Figure 7. Sugargraze variety at (a) 20 days and (b) 50 days after planting at MPOB Research Station in Teluk Intan, Perak.

planting season. Results of this study indicated that one planting season took almost six months to complete with four harvesting rounds. Generally, two rounds of planting can be conducted in one year depending on the climatic condition. Results of this study showed that Sugargraze variety produced the highest fresh and DM weight in four MPOB Research Stations, *i.e.*, Keratong, Pahang (8.83 t ha^{-1} and 2.38 t ha^{-1}), Kluang, Johor (63.69 t ha^{-1} and 11.14 t ha^{-1}), Lahad Datu, Sabah (100.96 t ha^{-1} and 18.23 t ha^{-1}) and Teluk Intan, Perak (62.68 t ha^{-1} and 7.49 t ha^{-1}) except for BMR Revolution variety which recorded higher at Ladang MAAH, KLIA (48.03 t ha^{-1} and 8.26 t ha^{-1}). Results of the study in Lahad Datu indicated that higher DM yield of forage sorghum compared to other locations. The DM of fodder yield was a little bit higher than reported by Meena *et al.* (2020) and Gnanagobal and Sinniah (2018). Meena *et al.* (2020) reported that Sugargraze produced fresh and DM yields of 56.37 t ha^{-1} and 15.13 t ha^{-1}, respectively. However, Gnanagobal and Sinniah (2018) recorded an average DM yield of 14.1 t ha^{-1} for Sugargraze. Bhat (2019) reported that forage sorghum has more biomass production potential in limited moisture regimes and forage quality comparable to that of forage maize. It has a good source of roughage for the livestock in the warm seasons and the tropics.

The study indicated that Sugargraze variety performed well in four MPOB's Stations except BMR Revolution performed better in Ladang MAAH, KLIA. Both of these forage sorghum varieties had better DM percentages compared to the rest of the tested varieties that contributed to the higher dry fodder yield per hectare.

Forage Sorghum Nutritional Values

All the different sorghum varieties were analysed to determine their nutritional values for livestock feed. The forages were analysed for DM, CP, fibre (acid detergent or neutral detergent) and

TABLE 13. ESTIMATED FRESH AND DRY WEIGHT OF FORAGE SORGHUM YIELD*

MPOB Research Station	Variety	Total fresh weight (t ha^{-1} season^{-1}*)	Total dry weight (t ha^{-1} season^{-1}*)	Dry matter percentage (%)
Keratong, Pahang	Superdan	8.52	2.04	23.94
	Jumbo	10.43	2.78	26.65
	Pacific BMR	9.20	2.40	26.08
	Sugargraze	8.83	2.38	26.95
	BMR Revolution	9.53	2.35	24.65
Ladang MAAH, KLIA, Sepang, Selangor	Superdan	42.27	6.49	15.35
	Jumbo	44.03	7.19	16.33
	Pacific BMR	40.64	6.93	17.05
	Sugargraze	46.32	7.89	17.03
	BMR Revolution	48.03	8.25	17.17
Kluang, Johor	Superdan	39.09	6.33	16.19
	Jumbo	42.03	7.13	16.96
	Pacific BMR	42.85	7.27	16.97
	Sugargraze	63.69	11.14	17.49
	BMR Revolution	47.96	8.43	17.58
Lahad Datu, Sabah	Superdan	51.38	8.68	16.89
	Jumbo	73.65	11.67	15.84
	Pacific BMR	67.67	12.22	18.06
	Sugargraze	100.96	18.23	18.06
	BMR Revolution	65.28	12.97	19.86
Teluk Intan, Perak	Superdan	26.77	3.42	12.78
	Jumbo	37.56	5.32	14.16
	Pacific BMR	34.15	4.60	13.46
	Sugargraze	62.68	7.49	11.95
	BMR Revolution	37.17	5.35	14.39

Note: * Six months per season and four harvests.

available energy (Weiss *et al.*, 1999). The nutrient information of the forages such as mineral content is needed to balance the diets. Forage quality affects feed intake and the amount of concentrate needed to balance the diet. Digestibility of a diet has a major influence on feed intake by livestock. Fibre is generally less digestible than non-fibre components; therefore, high-fibre feeds such as forages are less digestible than low-fibre feeds such as grains. High quality forages such as corn silage and vegetative grasses are usually digestible enough that feed intake is not restricted significantly.

Generally, CP content is positively correlated with quality. Normally, high-protein forages generally are high-quality forages. The CP content is positively correlated to the energy content of forages. High protein forages generally are more digestible and provide more energy per kilogram than low-protein forages. *Table 14* shows the average nutritional values for five forage sorghum varieties that were integrated with oil palm at MPOB/ MAAH Plantation in KLIA, Sepang. The results showed that the CP values were almost comparable for all varieties except for Sugargraze, which was slightly lower.

Plant fibre is composed largely of cellulose and hemicellulose. The amount of cellulose is relatively constant among forage, but the amount of hemicellulose differs greatly between grasses and legumes. Cellulose is the primary constituent of ADF, but NDF contains both cellulose and hemicellulose. Therefore, grasses and legumes may have similar ADF values, but NDF values will almost always be substantially higher for grasses. High quality forages will contain 55% to 70% NDF (30% to 40% ADF). Low quality forages contain 70% to 80% ADF. The results in *Table 14* showed that all the forage sorghum varieties were in the category of high-quality forage because the value was in the ranges value of ADF and NDF.

TDN is calculated by estimating the difference between the amount of nutrient ingested minus the amount of nutrient excreted in the faeces, expressed as a percentage of the nutrient ingested. It could also be estimated through ADF content. For instance, if the ADF content is 30%, the estimated TDN content of feed could be 61.85% in the legume or 66.84% in corn silage (Deanne and Kevin, 1990). The study results showed that the TDN values of all the five sorghum varieties were within the ranges of 57.10% to 63.93%.

The ME value of a feed is a measure of the energy available to an animal after accounting for the energy losses in faeces, urine, and methane. ME values are expressed as megajoules per kilogram of DM (MJ kg^{-1}). It is closely related to the digestibility of the feed. When digestibility is high, the ME will be high (Stuart, 2002). The results in *Table 14* showed that ME values were almost similar for all forage sorghum varieties.

Pests and Diseases

The yield of forage sorghum was determined by the variety and application of good agricultural practices (GAP) in its management. Several agricultural practices such as good land preparation, fertilisation programme, pest and disease control and harvesting programme must be carried out according to GAP to ensure the integrated forage sorghum produced a higher yield.

Generally, pests and diseases are not the major problems in cultivating forage sorghum for livestock. Similarly, Khalin *et al.* (2020) reported that Romania had significantly expanded the planted area with sorghum in 2007-2017 owing to its advantages: Strong adaptation to diverse soil types, tolerance to high temperatures and low rainfalls, resistance to diseases and pests, inexpensive inputs, and production cost. During the study, we had

TABLE 14. NUTRITIONAL VALUE OF FORAGE SORGHUM INTEGRATED WITH OIL PALM AT DIFFERENT HARVESTING CYCLE

Nutrition	Superdan	Jumbo	Pacific BMR	Sugargraze	BMR Revolution
Crude protein (%)	16.80	17.10	17.10	14.90	16.20
Crude fat (%)	3.20	2.90	3.40	2.80	3.30
Crude fibre (%)	40.90	36.10	27.60	32.80	33.60
Ash (%)	8.00	8.40	9.50	8.90	8.00
Calcium (%)	0.42	0.39	0.39	0.32	0.33
Phosphorus (%)	0.28	0.26	0.28	0.28	0.29
Neutral detergent fibre (%)	64.90	68.00	64.40	61.70	63.90
Acid detergent fibre (%)	37.70	39.60	36.90	35.30	35.50
Hemicellulose (%)	27.30	28.40	27.50	26.40	28.30
Total digestible nutrient (%)	57.90	57.10	63.90	57.10	61.00
Metabolisable energy (MJ/kg)	8.65	8.50	9.63	8.51	9.16

found that grasshopper, *Valanga* sp. attacked forage sorghum at MPOB Research Station in Kluang, Johor (*Figure 8*). Nutrient disorder in the form of the red tip was detected on forage sorghum at MPOB Research Station in Teluk Intan, Perak (*Figure 9*) and both incidents were not serious. These incidents happened during the dry season. The cause of the red tip was not fully understood but it was believed to be due to deficiencies of nitrogen (N), phosphorus (P), magnesium (Mg) and zinc (Zn). This disorder was controlled by the application of nitrogen fertiliser and sorghum rotation with legume crops.

Effect of Forage Sorghum Integration on Oil Palm Yield

Table 15 compares the average FFB weight for the double avenue oil palm integrated with forage sorghum to the control oil palm plot without forage sorghum integration at Ladang MAAH KLIA. The data was collected for the first five years of harvesting. The results showed that the FFB yield of double avenue oil palm and sorghum integration plots were not significantly different to the control oil palm plots except for the third year FFB yield. These results showed that integrating sorghum with a double avenue oil palm planting system did not reduce oil palm yield. Integration of other crops in double avenue oil palm planting will not result in a negative impact on FFB production if done systematically (Raja Zulkifli *et al.*, 2009).

Figure 8. Valanga *sp. attacks on the leaf of forage sorghum.*

Cost and Return Analysis

Economic analysis was conducted on the oil palm-forage sorghum integration. Total production cost for integrating forage sorghum in the double avenue oil palm planting area was RM5580/ha/season (*Table 16*).

Table 17 shows the cost analysis for fresh fodder production at an average yield of 157 t ha^{-1} yr^{-1} and the price of fresh fodder at RM120 t^{-1}. Based on that assumption, the gross revenue and net revenue per hectare were RM18 840 and RM7680, respectively. The monthly income per hectare from forage sorghum was RM640. The oil palm revenue was calculated based on the FFB yield of the trial plots and the average FFB price of RM540 t^{-1}. Based on this FFB price and FFB yield of 25.40 t ha^{-1} yr^{-1}, the gross and net revenue per hectare was RM13 716 and RM8128, respectively. The monthly income from oil palm was RM677. The total monthly income from the integration of forage sorghum with oil palm was RM1317.

However, the oil palm double avenue-forage sorghum integrated plot produced a slightly lower FFB yield compared to the conventional triangular oil palm control (N148). The difference in FFB yield was 2.45 t ha^{-1} yr^{-1}. But the difference in FFB yield was only 0.80 t ha^{-1} yr^{-1} between the oil palm double avenue-forage sorghum integrated plot compared to the conventional triangular oil palm control (N136). Higher FFB yield in the conventional triangular oil palm control (N148) was due to

(a)

(b)

Figure 9. Red tip symptom on (a) whole sorghum plants and (b) leaves.

TABLE 15. AVERAGE FFB YIELD AT LADANG MAAH, KLIA (t ha^{-1} yr^{-1})

Oil palm planting system	Year 1	Year 2	Year 3	Year 4*	Year 5	Average	+/-
Double avenue oil palm integrated with sorghum	3.74 ^{a}	10.30 ^{a}	23.46 ^{bc}	23.13 ^{abcd}	24.62 ^{abcd}	17.05	-
Double avenue oil palm control	4.92 ^{a}	9.77 ^{a}	23.93 ^{bc}	20.63 ^{d}	21.35 ^{d}	16.12	-0.93
Conventional triangular oil palm control (N136)	3.52 ^{a}	9.04 ^{a}	24.66 ^{abc}	26.31 ^{ab}	25.71 ^{abc}	17.85	+0.80
Conventional triangular oil palm control (N148)	4.29 ^{a}	11.42 ^{a}	28.22 ^{a}	26.64 ^{a}	26.92 ^{ab}	19.50	+2.45

Note: * The FFB yield in Year 4 decreased due to severe infestation of bagworm.

an extra number of 12 palms in the plot. But, the conventional triangular oil palm control (N136) that has similar palm density per hectare with the oil palm double avenue-forage sorghum integration plot produced similar FFB yields. However, the loss of return from FFB reduction by adopting a double avenue oil planting system can be compensated by forage sorghum integration.

CONCLUSION

Forage sorghum is technically and economically viable for planting in the double avenue oil palm planting area. In this study, the Sugargraze variety is the most suitable forage sorghum variety for commercial cultivation as an integration crop for fodder production in the oil palm planting area. This was followed by BMR Revolution, Pacific BMR, Jumbo and Superdan varieties. This integration of forage sorghum will optimise the oil palm land use and maximise income per unit land area in order to generate additional income for oil palm growers. To ensure that the integrated forage sorghum produces the highest fodder yield, good agricultural practices for forage sorghum cultivation must be practised by the growers.

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TABLE 16. PRODUCTION COST OF FORAGE SORGHUM INTEGRATION WITH OIL PALM (RM/ha/season*)

Input/activities	Input cost/contract (RM)	Labour		Total (RM)
		Man-day	Cost (RM)	
Seed	400.00	-	-	400.00
Land preparation	850.00	-	-	850.00
Planting	-	10	300.00	300.00
Liming and fertiliser	2 180.00	13	390.00	2 570.00
Weeding	80.00	9	270.00	350.00
Pest and disease control	150.00	2	60.00	210.00
Harvesting	-	30	900.00	900.00
Total cost	**3 660.00**	**64**	**1 920.00**	**5 580.00**

Note: * Six months per season and four harvest cycles.

TABLE 17. ESTIMATED REVENUE FROM FORAGE SORGHUM INTEGRATION WITH OIL PALM (RM ha^{-1} yr^{-1})

Item	Forage sorghum	Oil palm	Total (RM)
	Price: RM120 t^{-1}	Price: RM540 t^{-1}	
Fresh yield (t ha^{-1} yr^{-1})	157.00	25.40	-
Gross return (RM ha^{-1})	18 840.00	13 716.00	32 556.00
Total cost (RM ha^{-1})	11 160.00	5 588.00	16 748.00
Net return (RM ha^{-1})	7 680.00	8 128.00	15 808.00
Monthly income (RM)	640.00	677.00	1 317.00

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