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Effects of thermal heat units on the phenology and yield of kenaf in the sorghum/kenaf/okra intercrop in the forest-savanna transition zone of Nigeria

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ABSTRACT

This study investigated the effects of thermal heat units on the phenology and yield of kenaf in the sorghum/kenaf/okra intercrop at the Teaching and Research Farm of the Department of Water Resources Management and Agricultural Meteorology, Federal University of Agriculture, Abeokuta, Nigeria during the 2011 and 2012 planting seasons. One kenaf (Cuba 108) and okra (NHAe 47-4) cultivars and two sorghum cultivars (Janare and Farin-Dawa) were intercropped to form 11 treatments. The treatments were randomised in a complete block design, with three replicates. Daily agrometeorological data were collected from the agrometeorological station of the Department of Water Resources Management and Agricultural Meteorology, Federal University of Agriculture, Abeokuta, Nigeria, to determine the growing degree days (GDD). Helio thermal units (HTU), photothermal units (PTU), relative temperature disparity (RTD), and heat unit efficiency (HUE) using empirical formulae. The results of the study showed that the accumulated GDDs, PTU, HTU, and RTD required to attain different growth stages of kenaf with sorghum and okra in the sole, two-, and three-tier stands were significantly affected. The HUE values of kenaf in the sole stand were significantly higher than those in their mixtures. HUE correlated positively and significantly with the yield of kenaf bast fibre (0.986**) and seed (0.801**), indicating that the temperature was efficiently utilised by the crops in sole and mixtures. Hence, it may be concluded that kenaf can be incorporated with sorghum and okra to give a new crop combination.

Keywords: Heat units, kenaf, fibre, food, phenology, yield

INTRODUCTION

One of the biggest challenges facing many developing countries, including Nigeria, in the 21st century is the production of food sufficient for human consumption and fibre for use in pulp and paper mills. Global food and fibre shortages are caused by population growth, climate change, and variability. More than 800 million people in developing countries do not have sufficient food (FAO, IFAD, UNICEF, WFP and WHO, 2021), and the demand for the global consumption of papermaking fibres is predicted to increase from approximately 300 million tons in 1996 - 97 to approximately 425 million tons in 2010, an increase of 125 million tons (Ashori, 2006). with a compound annual growth rate of 4.7% (Liu, 2003). Today, in Nigeria, changes in land use and climate patterns affect food and fibre production as well as change the distribution of agroecological zones. To gradually eliminate food insecurity in changing climates, the production of food and fibre should be exploited in the marginal agroecological zones of Nigeria. Utilising the agroecological suitability of Nigerian forests and savannah agroecological transitions for the cultivation of plant mixtures to meet growing demand is a good strategy for boosting food and fibre production. Farmers' choice of staple food and preference is one of the factors influencing decisions on crop selection in the intercropping system, which has inadvertently affected the production of fibre. To meet the demand for other basic human needs, such as fibre, there is a need to develop a new crop combination into the existing intercropping system in Nigeria.

Kenaf (Hibiscus cannabinus L.) is an annual crop that is of great interest as a source of cheap natural fibre and energy. The crop has shown potential for use as both fibre and feed (Taylor, 1992; Webber, 1999; White et al., 1994), and can be used to mitigate global warming by absorbing carbon dioxide gas because of its rapid growth rate (Rymza, 1999). Kenaf is 3 - 5 times more productive per unit area than pulp wood and produces pulp equal to or better than other wood pulps (Theisen *et al*., 1978). In addition, kenaf plants absorb 3–5 times the CO2 and NO2 from forests, which is one of the reasons why they have been planted in some Japanese cities to improve air quality and efficiently purify the environment (Liu, 2000; Lam, 2000).

Research efforts to overcome the global shortages of food and fibre, in this part of the world, have resulted in mixing two or more crops. Considering the number of existing crop combinations in Nigeria, little research has been conducted on sorghum, kenaf, and okra in soles and mixtures (Bello 1997; Raji and Fadare 2003; Raji 2008; Kassim et al. 2019). Even existing agroclimatic research has focused more on moisture-based indices, leaving a wide gap of information in scientific research on thermal-based indices. Therefore, this study aimed to investigate the effects of thermal heat units on the phenology and yield of kenaf in a sorghum/kenaf/okra intercrop.

MATERIALS AND METHODS

Experimental Site

The experiments were conducted during the 2011 and 2012 cropping years at the Federal University of Agriculture, Abeokuta, Nigeria, situated at an altitude of 141 m above the mean sea level, 70 °15 °N latitude, and 30 °25 °N longitude. The climate of the study area is tropical with distinct wet and dry seasons. The area is located within a region characterised by a bimodal rainfall pattern (which commences in March, is plentiful in July and September, and has a short dry spell in August). The long dry period extends from November to March. The annual rainfall in the study area and its environs ranges between 1400 and 1500 mm. The region is characterised by a relatively high temperature, with a mean annual air temperature of 30 °C. Humidity is lowest (37–54 %) at the peak of the dry season in February and highest at the peak of the rainy season between June and September (78–85 %) (Eruola, 2011). The experiment was conducted on well-drained tropical ferruginous soil with a sandy-loam surface horizon underlain by weakly developed clayey, mottled, and occasionally concretionary subsoil. The A-horizon of the soil had 83.3% sand, 4.6% silt, and 12.1 % clay (Adetunji, 1991) and a pH of 6.2. The soil is suitable for the cultivation of the crops

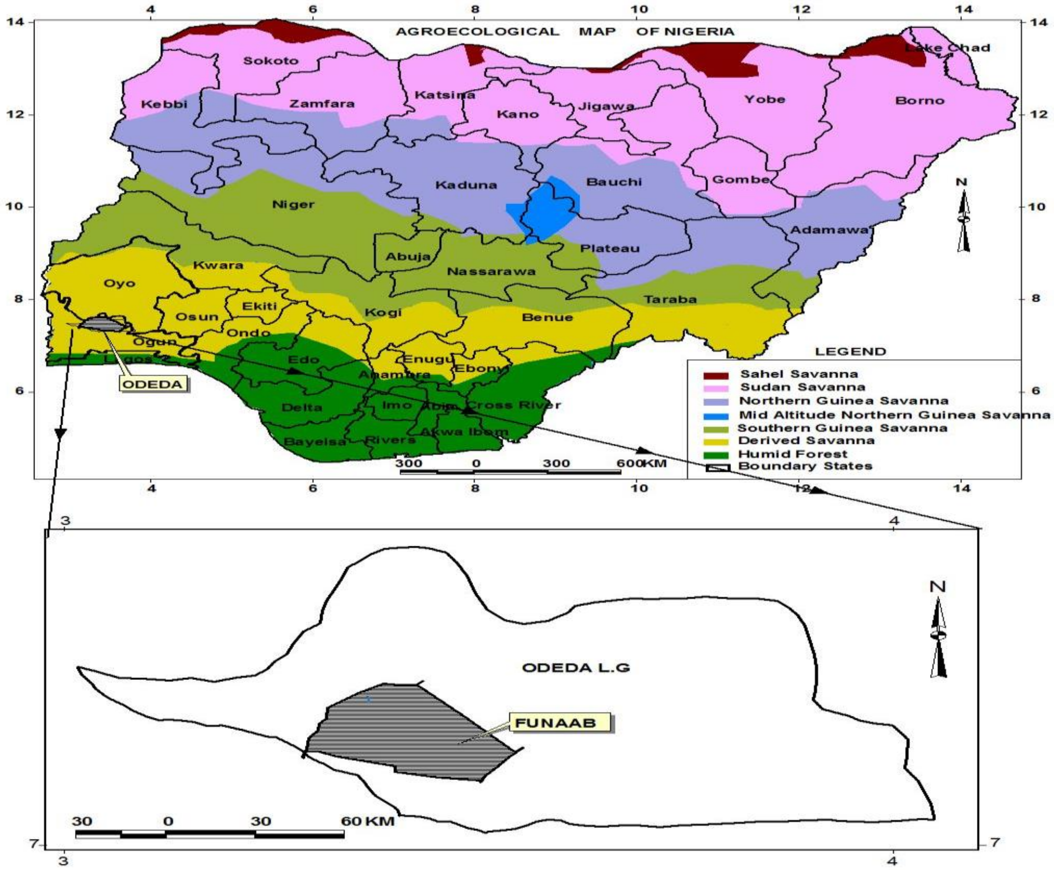

Figure 1: Map of the study area

Field Methods and Experimental Design

A gross plot size of 45 m by 25 m was cleared, stumped, and ridged manually with the use of cutlass and hoe with each plot size of 5 m wide and 3 m long, with a walking path of 1 m. Two sorghum cultivars, Janare (Sr) and Farin-Dawa (Sw), were mixed with one kenaf (K), Cuba 108, and okra (O), NHAe 47-4 cultivars to form 11 treatments (Sr, Sw, K, O, SrK, SwK, SrO, SwO, KO, SrKO, and SwKO). The treatments were replicated three times in a randomised complete block design. The plant spacing for sole sorghum, kenaf and okra were 90 x 60 cm, 0.75 x 0.6 cm, and 90 x 30 cm, respectively, while plant spacing of 90 x 90 cm was used for the crops in intercrops.

The crops were sown after full rains were established on 9 June 2011 and 29 June 2012. Four sorghum and kenaf seeds and two okra seeds were dibbled in each plot at a depth of 2.5 cm. To maintain the required plant population, excess seedlings were thinned out 20 days after sowing to two plants per stand for sorghum and kenaf, and one plant per stand for okra.

Data Collection

Agro-climatic Data

During the experimental years, daily observations of maximum and minimum air temperatures (T, °C), bright sunshine hours (hrs) and day length (hrs) were collected from the agro-meteorological station of the Department of Water Resources Management and Agricultural Meteorology, the Federal University of Agriculture, Abeokuta, Nigeria.

The heat units determined during the study were growing degree days (GDD) (°C day), helio thermal unit HTU (°C day), photo thermal unit (PTU) (°C day), relative temperature disparity (RTD) (°C day), and heat unit efficiency (HUE) (kgha-1/°C day). The Instat+ statistical package was employed to determine the accumulated GDD, while the remaining heat units were determined using the empirical formulae in Table 1.

Table 1: Expression of heat unit empirical formula

Equation	Reference
$HTU = \sum_{i=1}^{n} GDD \times SSH$	Rajput, 1987
$PTU = \sum_{i=1}^{n} GDD \times L$	Chankravarthy and Sastry, 1985
$RTD = \frac{\sum_{i=1}^{n} (T_{max} - T_{min})}{T_{max}} \times 100$	(Rajput, 1987)
$HUE = Yield \div GDD$	Haider *et al.*, 2003

where,

T_{max} = Maximum temperature (˚C)

T_{min} = Minimum temperature (˚C)

Tb = Base temperature (˚C)

L = Day length (hrs)

SSH = Sunshine hour (hrs)

A base temperature limit of 10 °C was used for sorghum/kenaf/okra development, following the procedure of Sowniya et al. (2022).

Agronomic Data

The phenological growth stages considered were the establishment, vegetative, reproductive, and physiological maturity stages. Some yield parameters determined included panicle length (cm) and grain yield (t ha-1) for sorghum; bast fibre yield (t ha-1) and seed yield (t ha-1) for kenaf; and the number of fruit/plants, fruit weight (g), and fruit yield (t ha-1) for okra. The yield parameters of sorghum, kenaf, and okra were determined using standard procedures.

Analysis of Data

The data collected from the study were analysed according to the analysis of variance performed on the yield parameters, using a randomised complete block design (SAS, 2000). The means for each parameter for each component crop were compared using the least significant difference (LSD) technique.

RESULTS AND DISCUSSION

Table 2 revealed that the accumulated GDD ranged from 1213 ˚C to 1649.2 ˚C days, from 1350.3 ˚C to 1768.3 ˚C days and from 2585.3 ˚C to 3153 ˚C days in the completion of different phenological stages of 50% flowering, 50% fruiting and physiological maturity, respectively. The accumulated value of GDD experienced by the kenaf crop during each phenological stage was significantly different (P < 0.05) for each treatment. The highest accumulated GDD was recorded in the SwKO treatment compared with the other treatments at the completion of different phenological stages. The accumulated GDD value for each treatment was the highest for each phenological stage of kenaf crop in both sole and mixed cropping in 2011 and the lowest in the 2012 cropping season. Table 7 showed a significant negative correlation between kenaf seed yield and accumulated PTU at panicle initiation (-0.59**), fruiting (-0.66**), and harvesting (-0.47**). Similarly, a negative correlation was observed between fibre yield and accumulated PTU at flowering (-0.34*), fruiting (-0.39*), and harvesting (-0.24).

Table 3 showed that the PTU varied between 5883.1 and 19902.3 °C days, 1350.3 and 21411.7 °C days, and 7988.9 and 39166.3 °C days at the completion of different phenological stages of 50% flowering, 50% fruiting, and physiological maturity, respectively. The PTU values of the kenaf crop during each phenological stage were significantly different (P < 0.05) for each treatment. The PTU values for each treatment were highest at each phenological stage of the kenaf crop in both sole and mixed cropping in 2012 and lowest in the 2011 cropping year. A non-significant negative correlation was observed between kenaf fibre yield and PTU at panicle initiation (-0.05), fruiting (-0.24), and harvesting (-0.05). Similarly, a negative correlation was observed between seed yield and PTU at flowering (-0.28), fruiting (-0.56**), and harvesting (-0.36*) (Table 7).

Table 4 revealed that the HTU ranged from 7423.6 to 17064.9 °C days, 8111.8 °C to 19047.1 °C days, and 3754 to 33512 °C days at the completion of different phenological stages of 50% flowering, 50% fruiting, and physiological maturity, respectively. While the highest HTU was recorded in the SwKO treatment compared to the other treatments at the completion of vegetative and fruiting stages, SwKO and SrKO had the highest HTU at the completion of harvesting. The HTU values for each treatment were highest at each phenological stage of the kenaf crop in both sole and mixed cropping in 2012 and lowest in the 2011 cropping year. Table 7 shows that a negative correlation existed between the fibre yield of kenaf and HTU at panicle initiation (-0.25), fruiting (-0.16), and harvesting (0.10). However, the relationship was not statistically significant. However, positive correlations were observed between the seed yield and HTU at flowering (0.04), fruiting (0.13), and harvesting (0.39).

Table 5 showed that the RTD values to attain 50% flowering, 50% fruiting, and physiological maturity stages ranged from 26.3 to 38.3 ˚C days, 26.8 to 33.2 ˚C days, and 23.4 to 31 ˚C days, respectively. The RTD values of the treatments at each phenological stage were significantly different (P < 0.05). The highest accumulated RTD values were recorded in the SrKO, SwKO, and SwK treatments compared with the other treatments at the completion of 50% flowering, 50% fruiting, and physiological maturity stages, respectively. The RTD for each treatment was at a maximum to attain the physiological maturity stage during the 2012 cropping season.

Table 2: Accumulated growing degree days (˚C days) on phenological growth of kenaf in the sorghum/kenaf/okra in sole and mixtures

Treatments	50% Flowering		50% Fruiting		Physiological maturity	
	2011	2012	2011	2012	2011	2012
Sole cropping						
Kenaf (K)	1475	1295.9	1614.3	1429.1	2995.5	2585.2
Mixed cropping						
Kenaf+Okra (KO)	1401.4	1236.5	1560.9	1369.6	3017.9	2614.9
Red Sorghum+Kenaf (SrK)	1378.4	1213	1600.8	1356.9	3147.1	2685
White Sorghum+Kenaf (SwK)	1568.7	1336.5	1705.9	1473.7	3129.7	2687.7
Red Sorghum+Keanf+Okra SrKO)	1404.7	1207.3	1702.9	1350.3	3147.4	2702.1
White Sorghum+Kenaf+Okra (SwKO)	1649.2	1422	1768.3	1579.7	3153	2702.1
LSD (0.05)	41.11	49.02	51.49	57.62	72.74	60.73

Table 3: Photo thermal unit (˚C days) on phenological growth of kenaf in the sorghum/kenaf/okra in sole and mixtures

Treatments	50% Flowering		50% Fruiting		Physiological maturity	
	2011	2012	2011	2012	2011	2012
Sole cropping						
Kenaf (K)	17710.8	7040.3	19469.7	3951.5	37201.4	7995
Mixed cropping						
Kenaf+Okra (KO)	16789.9	7924.1	18793.9	1672.2	37483.9	7988.9
Red Sorghum+Kenaf (SrK)	16508.3	7556.1	19292.6	1493.9	39092.8	13594.1
White Sorghum+Kenaf (SwK)	18888.1	5883.1	20617.8	6725.9	38877	9890.5
Red Sorghum+Keanf+Okra SrKO)	16830.6	8044.7	20582.3	1350.3	39095.6	15131.9
White Sorghum+Kenaf+Okra (SwKO)	19902.3	3359.5	21411.7	9809.7	39166.3	15131.9
LSD (0.05)	563.75	4291.4	1002.88	2113.68	702.83	7077.35

Table 4: Helio thermal unit (˚C days) on phenological growth of kenaf in sorghum/kenaf/okra in sole and mixtures

Treatments	50% Flowering		50% Fruiting		Physiological maturity	
	2011	2012	2011	2012	2011	2012
Sole cropping						
Kenaf (K)	7423.6	14171.2	8111.8	17153.5	16816.8	32009.6
Mixed cropping						
Kenaf+Okra (KO)	9898	13723.3	9256.2	16410.3	18399.3	32389.3
Red Sorghum+Kenaf (SrK)	10895.4	11976	10247.5	16251.2	18256.1	33253.8
White Sorghum+Kenaf (SwK)	10895.1	15998.2	12231	17711.2	20541	33325.9
Red Sorghum+Kenaf+Okra SrKO)	11096.9	12463.6	11248	16169.4	13754.2	33512.2
White Sorghum+Kenaf+Okra (SwKO)	11711.9	17064.6	8670.2	19047.1	16711	33512.2
LSD (0.05)	1567.62	3995.63	3226.87	839.82	6909.14	814.04

Table 5: Relative thermal disparity (˚C days) on phenological growth of kenaf in sorghum/kenaf/okra in sole and mixtures

Treatments	50% Flowering		50% Fruiting		Physiological maturity	
	2011	2012	2011	2012	2011	2012
Sole cropping						
Kenaf (K)	29.6	31.9	26.8	30	26	26.9
Mixed cropping						
Kenaf+Okra (KO)	26.3	35.9	28.2	29	26	29.1
Red Sorghum+Kenaf (SrK)	27.1	35.3	32.7	28.7	23.4	29.7
White Sorghum+Kenaf (SwK)	34.4	30.5	28.3	31.2	24.4	32.6
Red Sorghum+Kenaf+Okra SrKO)	28.2	38.3	30.3	30	23.4	31
White Sorghum+Kenaf+Okra (SwKO)	27.4	29.9	32	33.2	24.6	31
LSD (0.05)	5.83	7.1	4.51	3.32	3.24	4.25

In addition, the RTD values to attain 50% flowering and 50% fruiting stages were at a maximum during the 2012 cropping season, whereas the SwK, SrK, and SrKO treatments at both stages were at a minimum. Correlation analysis at flowering (0.22), fruiting (-0.50**), and harvesting (0.11) indicated a negative correlation relationship existed at fruiting between fibre yield and RTD. Similarly, the correlation analysis of seed yield at the flowering (0.49**), fruiting (-0.41), and harvesting (0.32) stages indicated positive and negative relationships between seed yield and RTD at the flowering and fruiting stages (Table 7).

As shown in Table 6, all the treatments utilised heat more efficiently in the 2011 cropping year than in 2012, except for kenaf in the sole. The highest HUE in fibre and seed of kenaf were recorded in sole kenaf and SrKO treatments, respectively. During the 2011 cropping year, SwKO had the lowest HUE (0.22 kgha^{-1}/˚C day) followed by SrKO, SwK, SrK, and KO, whereas sole kenaf had the highest HUE (0.92 kgha^{-1}/˚C day). Similarly, in the 2012 cropping year, SwKO also had the lowest HUE (0.26 kgha^{-1}/˚C day) followed by SwK, KO, SrK, and sole kenaf while SrKO had the highest HUE (0.84 kgha^{-1}/˚C day). The heat use efficiency for kenaf seed was like that of kenaf bast fibre. The results further revealed that sole kenaf had the highest HUE (0.41 kgha^{-1}/˚C Day) followed by KO, SrK, and SwK with both having the same HUE values, while SwKO had the lowest HUE (0.09 kgha^{-1}/˚C day), closely followed by SwKO. During the 2012 cropping season, the highest HUE value was observed in SrKO (0.68 kgha^{-1}/˚C day) followed by SrK, sole kenaf, KO, SwK, and SwKO.

Table 6: Heat unit efficiency (kgha^{-1}/˚C day) on phenological growth of kenaf in sorghum/kenaf/okra in sole and mixtures

Treatments	HUE			
	Fibre		Seed	
	2011	2012	2011	2012
Sole cropping				
Kenaf (K)	0.92	0.73	0.41	0.39
Mixed cropping				
Kenaf+Okra (KO)	0.42	0.47	0.25	0.31
Red Sorghum+Kenaf (SrK)	0.39	0.54	0.12	0.41
White Sorghum+Kenaf (SwK)	0.29	0.43	0.12	0.20
Red Sorghum+Keanf+Okra SrKO)	0.31	0.84	0.10	0.68
White Sorghum+Kenaf+Okra (SwKO)	0.22	0.26	0.09	0.10
LSD (0.05)	0.09	0.07	0.03	0.06

Table 7: Correlation between accumulated heat units and kenaf yield at different phenological stages

	PTUFL	HTUFL	RTDFL	GDDHarv	PTUHarv	HTUHarv	RTDHarv	GDDFrt	PTUFrt	HTUFrt	RTDFrt	FibreHUE	SeedHUE	FibreYield	SeedYield
GDDFL	.690**	-.493**	-.470**	.743**	.722**	-.653**	-.497**	.914**	.846**	-.592**	0.081	-.447**	-.639**	-.343*	-.591**
PTUFL		-.880**	-.345*	.915**	.927**	-.894**	-.755**	.732**	.857**	-.900**	-0.225	-0.191	-.351*	-0.054	-0.279
HTUFL			0.318	-.790**	-.853**	.849**	.658**	-.567**	-.772**	.943**	.349*	-0.105	0.128	-0.253	0.041
RTDFL				-.491**	-.481**	.547**	.387*	-.507**	-.603**	.450**	-0.202	0.288	.521**	0.216	.490**
GDDHarv					.973**	-.905**	-.725**	.849**	.943**	-.825**	-0.004	-.378*	-.539**	-0.237	-.471**
PTUHarv						-.918**	-.765**	.814**	.940**	-.873**	-0.087	-0.268	-.440**	-0.121	-.364*
HTUHarv							.750**	-.796**	-.911**	.899**	0.048	0.234	.456**	0.095	.386*
RTDHarv								-.585**	-.694**	.680**	0.044	0.205	.365*	0.107	0.322
GDDFrt									.927**	-.631**	0.204	-.507**	-.713**	-.390*	-.662**
PTUFrt										-.813**	0.033	-.385*	-.632**	-0.24	-.561**
HTUFrt											0.237	-0.011	0.214	-0.157	0.131
RTDFrt												-.480**	-.377*	-.503**	-.405*
FibreHUE													.857**	.986**	.872**
SeedHUE														.801**	.995**
FibreYield															.831**

**Significant at P ≤ 0.01, *Significant at P ≤ 0.05

FL = Flowering, Harv = Harvesting, Frt = Fruiting

There were significant differences in the number of days to reach 50% flowering, 50% fruiting, and physiological maturity among the treatments (Table 8). The number of days to reach the measured phenology was highest during the 2011 cropping season. The highest number of days to reach the measured phenology was observed in the SwKO treatment, whereas the lowest number of days was recorded in SrK, except at maturity, where the lowest number of days was recorded in the KO treatment. In the 2011 cropping year, it took kenaf in both sole and mixed cropping between 77 days and 91 days, 86 days and 97 days, and 120 days and 175 days to attain 50% flowering, 50% fruiting and maturity stages, respectively. During the 2012 cropping year, the number of days to reach the 50% flowering, 50% fruiting, and maturity stages varied from 69 to 81, 77 to 89, and 120 to 151, respectively.

Bast fibre yield of kenaf in the sole and mixed standing was at the maximum and minimum for all treatments during the 2011 and 2012 cropping years. During the 2011 cropping season, the highest bast fibre yield was recorded in K treatment (2.75 ton/ha), followed by KO (1.27 ton/ha), SrK (1.23 ton/ha), SwK (1.18 ton/ha), SrKO (0.99 ton/ha) and SwKO (0.80 ton/ha). Similarly, during the 2012 cropping year, the highest bast fibre yield was observed in K treatment (2.07 ton/ha), followed by KO (1.22 ton/ha), and SrK (1.17 ton/ha); whereas the lowest bast fibre yield was recorded in SwKO (0.70 ton/ha), followed by SrKO (0.91 ton/ha), and SwK (1.11 ton/ha).

A similar trend was observed for the kenaf seed yield (Table 8). During the 2011 cropping year, the highest seed yield was recorded in K treatment (1.22 ton/ha), followed by KO (0.45 ton/ha), SwK (0.41 ton/ha), SrK (0.39 ton/ha), SrKO (0.31 ton/ha), and SwKO (0.26 ton/ha). Similarly, during the 2012 cropping year, the highest seed yield was recorded in K treatment (1.15 ton/ha), followed by SrK (0.95 ton/ha),

Table 8: Phenology and some yield attributes of kenaf in sole and mixtures in the sorghum/kenaf/okra intercrop

Treatments	Number of days to 50% flowering		Number of days to 50% fruiting		Number of days to harvesting		Fibre yield (t/ha)		Seed yield (t/ha)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Sole cropping										
Kenaf (K)	82	74	89	81	162	139	2.75	2.07	1.22	1.15
Mixed cropping										
Kenaf+Okra (KO)	79	71	88	78	120	120	1.27	1.22	0.45	0.81
Red Sorghum+Kenaf (SrK)	77	70	86	77	172	142	1.23	1.17	0.39	0.95
White Sorghum+Kenaf (SwK)	87	76	93	83	174	139	1.18	1.11	0.41	0.84
Red Sorghum+Keanf+Okra SrKO)	78	69	93	77	169	151	0.99	0.91	0.31	0.39
White Sorghum+Kenaf+Okra (SwKO)	91	81	97	89	175	148	0.80	0.70	0.26	0.34
LSD (0.05)	2.09	2.52	3.79	3.21	2.35	NS	0.12	0.06	0.06	0.10

ton/ha), and SwK (0.84 ton/ha). While the lowest seed yield was recorded in SwKO (0.34 ton/ha), followed by SrKO (0.39 ton/ha), and KO (0.81 ton/ha).

Similarly, PTU, HTU, and RTD were significantly affected by the cropping year and cropping system. The PTU, HTU, and RTD consumed by kenaf in the sole stand and mixtures at various phenological stages were higher in 2011 than in 2012. This could be attributed to the exposure of the crop to a high mean daily temperature in 2011. PTU, HTU, and RTD did not affect the bast fibre yield of kenaf in the present study. The values of heat unit efficiency (HUE) of kenaf in the sole stand were significantly higher as compared to their mixtures in both cropping years. A significant positive relationship ($P < 0.01$) existed between kenaf yield in the sole stand and heat unit efficiency. A similar relationship has been reported by Haider et al. (2003) and Thavaprakaash et al. (2007).

In the present study, kenaf height in sorghum, kenaf, and okra intercrops differed significantly depending on the cropping system. The kenaf sole stand had a higher plant height than that of its respective mixtures. This can be attributed to the competition-free environment. This result is in agreement with those of Anil (2007) and Makinde et al. (2011). Kenaf in 2-tier mixtures had significantly higher plant heights than their 3-tier mixtures in the present study. This might be attributed to the severity of competition for growth resources owing to the number of component crops in the mixture and the heat utilisation of the kenaf. Yield reductions involving one or all intercropping components have been reported by Olasantan (2001), Adeniyan (2007), and Kassim et al. (2019). They reasoned that crops under mixtures were unable to utilise nutrients and moisture more efficiently owing to inter-species competition, whereas these factors were advantageous for sole cropping. Hence, the results of this study revealed that the cropping system had a significant effect on kenaf crop yield. The findings of Parlawar et al. (1998), Misra et al. (2000), Subbian and Selvaraju (2000), and Angadi et al. (2004) found that the grain yield of sole crops was higher than that of their mixtures, which corroborated the results of this study.

CONCLUSION

This study showed that heat units affect the yield of kenaf crops, even though the study area is a rainfed region. In addition, the heat use efficiency showed a positive relationship with the kenaf yield in both the sole and mixtures, hence, the production of food and fibre in the country can be boosted by incorporating sorghum, kenaf, and okra intercrop into the existing crop combination.

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