Original Research Article

Effects of shade regimes and varying seasons of irrigation on survival, developmental pattern and yield of field grown cacao (*Theobroma cacao*).

Abstract

Field experiments were conducted at the Teaching and Research Farm, Federal University of Technology Akure, Nigeria between 2012/2013 to 2014/2015 growing seasons to investigate the effects of varying dry season drip irrigation and shade regimes on field survival, development and yield of cacao. The treatments of shade regimes regime are (dense, moderate and the open sun) and the irrigation regimes (consisting of three, two and one dry season irrigation after transplanting). From the results, it was discovered that combined effects of moderate and dense shade with continuous three years irrigation enhances field survival and establishment of cacao but with a significantly lower effects on growth parameters like stem girth, branch number, and canopy size compared to those with continuous three years irrigation under open-sun. More so, plant height of cacao plants were significantly positively influenced by dense and moderate shades but with thinner stem girth compared with open-sun plots with thicker girth, higher branch number, and better canopy sizes at first and second growing season. In the third year, open-sun plots with two and three continuous dry season irrigation were significantly higher in plant height, girth, branch number and canopy sizes. In addition, increased cacao percentage survival were significantly influenced by irrigation and shade. Meanwhile, stand mortality were highest under dense and moderate shaded plots without irrigation in the second and third dry season (67%), followed by those without irrigation only in the second dry season (58%) and (52%) in those without irrigation in only the third dry season. Pod production were significantly higher with open-sun treatments that were irrigated throughout the three dry season with the average pod production of 12, 67 and 169 pods/plant in the 1st, 2nd and 3rd year. Moderate and densely shaded cacao was significantly lower in pod production compared to those under open-sun.

Key words: Cacao, canopy, dry season, irrigation, shade, survival.

Introduction

Several contrasting views on the effects of shade in cocoa farming have been advanced by various scholars. Anglaaere (2005) recounted that traditionally in West Africa, cocoa shade relates to the density of forest trees left in the field after initial clearing of the forest. Some writers (e.g. Padi and Owusu, 1998; Ruff and Zadi, 1998) contend that the main objective for growing cocoa under shade in the past, was to lengthen the economic life of the cocoa tree, the technical difficulty of cutting down large trees due to absence of necessary equipment in those days and or socio-cultural reasons.

Plant biomass and associated carbon storage are higher in shaded than unshaded cacao (Bisseleua *et al.*, 2009). In Indonesia, standing above-ground plant biomass was significantly lower in agroforestry with reduced canopy cover, mainly due to the removal of large trees (Steffan-Dewenter et al., 2007). This reduction corresponds to a loss in above-ground carbon storage of roughly 100t C ha^{-1} via conversion of mainly undisturbed natural forest into low-shade agroforestry systems (Steffan-Dewenter *et al.*, 2007).

Large-scale removal of rainforests is likely to cause a warmer and drier climate, leading to reduced cloud formation and upward shifts of cloud condensation layers (Lawton *et al.*, 2001). Changing patterns of temperature and precipitation threaten agriculture in tropical countries.

Air and soil temperatures are lower and air humidity levels higher under shade, which often reduces water stress for cacao (Lin, Perfecto and Vandermeer, 2008). Shade trees reduce evaporative demand and, hence, drought stress of cacao plants. In a cacao ⁄ Gliricidia agroforest in Sulawesi, increased canopy cover from shade trees has been shown to enhance water uptake and increase cacao stem diameter and leaf area (Kohler *et al.*, 2009). Enhanced vegetative growth under shade trees has also been observed in cacao stands in Ghana (Isaac *et al.*, 2007b). Shade trees in cacao enhance rainfall interception and thereby reduce water input to the soil (Dietz *et al.*, 2006). Shade trees in agroforests are often assumed to affect negatively growth and yield of cacao plants through competitive water use, but empirical studies have shown positive effects o f plant species specific, complementary resource use in agroforestry systems (Ong *et al.*, 2004). An understanding of the different root attributes of inter cropped tree, such as contrasting spatial rooting pattern, root morphology, and mycorrhizal status, is important to achieving such complementary resource use (Ewel & Mazzarino, 2008).

Materials and methods

Field experiments were conducted at the Teaching and Research Farm of the Federal University of Technology Akure, Nigeria between 2012/2013 to 2014/2015 growing seasons to investigate the effects of varying seasons of dry season drip irrigation and varying shade regimes on field survival, development and yield of cacao. Seeds of CRIN TC4 cocoa variety were gotten from Cocoa Research Institute of Nigeria, Ibadan in January, 2012 and 2013. The seeds were raised to seedlings and were later transplanted to the field in June/July of 2012 and 2013 respectively. The experiment design was a split plot design laid out as a 3x3 factorial experiment with three replications. The main plot which is the shade regimes consisting of dense shade, moderate and the open sun plots while the sub plots of irrigation regimes consisting of three seasons of dry season irrigation after transplanting, two seasons of dry season irrigation after transplanting and one seasons of dry season irrigation after transplanting. The field were manually cleared and shade plants (plantain) were planted based on the shade densities (dense shade plots: one cacao stand to one plantain stand; moderate shade plots: two cacao stand to one plantain stand and no shade plot: cacao stands with no plantain stand). Weed control were carried out manually throughout rainy season. At the onset of the dry season in December, 2012, 2013 and 2014 drip irrigation lines were laid out on the field to supply water to the seedlings during the entire period of the dry seasons. Overhead water tanks were installed on the field to supply water and the tanks were connected to water source (water dam) via a water pump and hose. The plots were irrigated for two hours at 7 days interval and the drip rate from the emitters were 2litres per hour via gravity flow.

Daily irrigation amount (I_{amt}) was calculated as:

$I_{amt} = K_{cp}$ * Epan * irrigation interval (days)………………………. i

where: K_{cp} is pan coefficient and Epan is the amount of cumulative evaporation during an irrigation interval (mm). One plant-pan coefficient was adopted to determine the irrigation levels ($K_{cp} = 0.70$). This corresponded to the amount of water for irrigation (mm) for the 7 days irrigation intervals.

The total amount (volume) of irrigation water applied/irrigation day was calculated using equation:

$$V = P * A * Epan * DI \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots ii$$

where, V, is the volume of irrigation water (L); P, wetting percentage (taken as 100 % for row crops); A, is plot area (m^2); $Ep_{an,}$ the amount of cumulative evaporation during an irrigation interval (mm); DI, irrigation levels (7 days interval). Irrigations occurred on the respective treatments when Epan reached target values.

Agronomic parameters like plant height, stem girth, branch number and leaf area index were measured on the cacao plants at four weeks interval while percent survival, mortality rate were taken at the onset and cessation of rainy season, flower initiation and pod formation date were taken across the treatments, yield parameters like number of cherelles, pod yield and bean yield were taken at the end of every harvest season. The effects of irrigation on off season flowering and fruiting was also monitored. The collected data were subjected to statistical analysis using GENSTART and the means were separated using Tukey test.

Results:

Effects of shade regimes on percent survival of cacao at on-set and end of dry seasons

Table 1 represents the performance of transplanted cacao in term of stand survival on the field as affected by varying shade regimes at the beginning and end of the first, second and third dry season in 2012/13, 2013/14 and 2014/15. From the results, ($P \leq 0.05$) no significant difference was observed in the percentage stand survival across the three shade regimes at the onset of the first dry season, at the end of the first dry season (April, 2013) the percent survival of cacao under dense and moderately shaded plots were significantly higher compared with the unshaded plot. In the second and third dry season, percent survival was significantly higher in densely shaded plots over the moderate and the no shade ones. A significantly higher percent stand mortality of 72.9 was recorded under no shade plot compared with those of 60.0 and 51.6 recorded under moderate and densely shaded plots respectively at the end of the third dry season (Table 2).

Table 3 shows the effects of varying season of irrigation on percent stand survival of field grown cacao. From the results, dry season irrigation enhances cacao field survival with less than 1% mortality at the end of first dry season. No significant difference among the treatments in term of percent survival at the end of the first dry season. In the second dry seasons, plots with only one season irrigation were significantly lower in percent stand survival compared with those with two and three seasons of irrigation. The percent survival under in plots without second and third season irrigation dropped from 99.5 to 60.2 and to 35.5 for first, second and third year respectively. Plots with only two seasons of irrigation also had a sharp increase in stand mortality in the third season as the percent stand survival dropped from 99.8 to 65.4 at the end of 2014/2015 dry season.

Table 4 represents the combine effects of shade and seasons of irrigation on survival of cacao at the onset and end of 2012/2013, 2013/2014 and 2014/2015 seasons. The results indicated that no significant difference was observed in the stand survival of the cacao during the 2012/2013 season. In 2013/2014, plots without second dry season irrigation were significantly lower in percent stand survival under the three shade regimes. During 2014/2015 season, plots with three seasons of irrigation had the highest percent survival above 97% while those with two seasons of irrigation had a significantly lower surviving rates of about 63% which is significantly higher compared with that of only one season irrigation of 34.7, 42.5 and 52.5 % for dense, moderate and No shade respectively. It was observed that percent survival of cacao tends to improve under no shade after two seasons of dry season irrigation. It was observed that moisture stress tolerance of cacao stands under no shade tends to increase after irrigation in the first two dry season.

Table 5 indicated the effects of shade regimes on percent number of flower and pod bearing stands in months after transplanting. It was observed that shading influenced early flower initiation at 13th month after transplanting compared with the no shade plots that flowers at 15th month. At the 15th month after transplanting, the percent number of flower bearing stands were significantly higher under moderate and dense shaded plots compared to that of no shade. In addition, the influence of moderate shade led to early pod production at 13th month with about 2.4% having pods. Dense and no shade plots begin pod production at 15th month. At 18th month, dense and moderate shaded plots produces a significantly higher number of pod bearing stands compared to the no shade plots.

Table 6 represent the effects of seasons of irrigation on percent number of flower and pod bearing stands between 10-18th month. It was observed that early flowering was influenced by treatment of irrigation as flower initiation was at 10th month after transplanting across all plots of irrigation treatment. 100% flowering was recorded at 15th month as a result of first dry season irrigation. Pod production rates were uniform across the three treatments of irrigation.

Table 7 revealed the combined effects of shade and seasons of irrigation on number of flower and pod bearing stands of cacao between 10-18th month after transplanting. It was observed that flower initiation suffered delay under densely shaded + irrigation plots (15th month) while moderate and no shade plots + irrigation begins flowering at 10th and 11th months after transplanting respectively. More so, at 15th month, percent number of stands with flower were significantly higher under no shade with irrigation compared with those of moderate and dense shade with irrigation. Similarly trends were observed in pod production as almost 100% stand under no shade produces pods at 18th month after transplant while under moderate and dense shaded plots had 32% and 26 % respectively at the same period.

Table 8 represents the effects of shade regimes on cacao pod yield during the main and mid-crop harvest. Considering the main crop harvest, no significant difference was observed between moderately shaded plots and the no shade plots in term of pod yield at 15th and 16th month after transplanting but were higher in production compare with the densely shaded plots. At 17th month after transplant, cacao plants under open sun (no shade) produced a significantly higher number of pods over those under moderate and dense shaded plots during the main crop harvest. During the mid-crop harvest (20-23rd month), pod yield was lower significantly under no shade plots compared to those under moderate and dense shade.

Table 9 shows the effects of dry season irrigation on pod yield during main and mid-crop harvest. The single effects of irrigation during the main crop harvest (15-18th month) showed no significant difference among the varying seasons of irrigation. During the mid-crop harvest, plots under two and three seasons of dry season irrigation produced a significantly higher number of pods compared to those under one season of irrigation.

Table 10 indicates the combine effects of shade regimes and varying dry season irrigation on pod yield of cacao during main and mid-crop harvest. Combination of no shade + two dry season irrigation and no shade + three dry season irrigation produced a significantly higher pod yield during the first main crop harvest (14-18th month after transplant) over that of combinations with moderate and dense shades. More so, between January-April, covering 19th-22nd month after transplanting, combination of dense and moderate shade with two and three seasons of irrigation favoured pod yield over those exposed to only one season of irrigation. During the second main crop harvest, 25-29th month after transplant, no shade plots + two and three seasons of irrigation produced a significantly higher pod yield over those with dense and moderate shades.

Discussion

The combined effects of moderate and dense plantain shade with continuous three years irrigation enhances field survival and establishment of cacao but with a significantly negative effects on some growth parameters like stem girth, branch number, and canopy size compared to cacao with continuous three years dry season irrigation under open sun (no shade). This was in conformity with the findings of Daymond *et al*, (2013) that high density shade impede young cacao growth and development as shade plant compete with both water and light thereby leading to reduced photosynthetic rate and low assimilate production.

More so, Boa *et.al*. (2000) reported that Fruit trees generally combined well with cacao though farmers said they provided fewer ecological services to cacao plants. Shade is not the most valuable feature according to farmers.

Kassam and smith, (2001) and Greenberg R (1998) resolved that soil evaporation decreases proportionally over the growing seasons as the ground surface is increasingly shaded by crops and shade plant canopy. These facts validated the significant effects of shade treatments on increased percent survival of cacao on the field after transplanting. Though, provision of water through dry season irrigation and un-hindered access to sunlight positively enhanced early establishment, survival, development and speedy canopy development in the no shade treatments which gave it a hedge over the shaded plots in shoot development and early production. This further confirm the early study of Famuwagun, (2016) that no shade cacao under irrigation performed better than the shaded ones.

Famuwagun, (2016), reported that shade alone support cacao seedlings survival on the field after transplanting up to 60% at the end of the first dry season which is in tandem with the findings from this research that shade alone influenced field survival of cacao but with a decreasing total stand survival at the second and third dry season. Cacao requires shade during its early stages of growth. This may be provided by temporary plants or by mature trees. There is no absolute requirement for shade once the cacao tree is established, unless there is no irrigation, in which case shade trees preserve soil moisture. The significantly higher plant height of cacao plants under moderate shades came with a thinner stem girth compared to those under open sun (no shade) with a thicker girth, higher branch number, and better canopy sizes at first and second growing season was as a result of competition between the cacao and the shade plants.

The substantial growth and development recorded in the third year with no shade plots with two and three dry season continuous irrigation were and increased cacao percentage survival were occasioned by irrigation. Second and third growing season consecutive irrigation influenced survival and establishment. Meanwhile that mortality were highest under plots of dense and moderate shades without irrigation in the second and third dry season (67%), followed by those without irrigation only in the second dry season (58%) and (52%) in those without irrigation in only the third dry season was as a result of completion for deficit in soil moisture and shallow root development/penetration in the soil. This was in line with the findings of Alvim *et.al.*, (1974a), Balasimha (1988), and Darusman, *et.al.*, (1997b).

Earliness in the commencement and progression towards key physiological events such as flowering and pod formation observed in this study, were consistent with earlier studies (Bell and Wright, 1998, Agele *et al*., 2004) while the high yield recorded (average pod production per plant in the 1st, 2nd and 3rd year as 12, 67 and 169 respectively while those irrigated for first and second year only produces 13, 60 and 122 pods for 1st, 2nd and 3rd year) under no shade treatments that were irrigated throughout the three dry season was as a result of unrestricted growth and development in both rainy and dry season, un-hindered access to solar energy and farm sanitation and management practices. This was supported by Famuwagun, (2016) and Agele *et.al*., (2016) that dry season irrigation ensure continuous supply of needed moisture for growth and development of cacao.

The low pod yield recorded under shaded cacao plots were due to excessive effects of shade on assimilate production vis-à-vis dry matter accumulation which impeded growth and development. This was in tandem with the findings of Merkel *et. al*., (1994) that un-hindered insolation enhance good vigour and improved pod yield in cacao. The significantly higher proportion of trees bearing flowers at 14 and 15 MAT in open sun compare with the moderate and dense shaded cacao might have resulted from the initial differential vigour of growth between the No shade plots and shaded ones. These advantages also extended to the higher proportion of trees bearing pods under open sun (no shade). Opeke, (2006) reported that flower development in cacao is determined predominantly by vigour of growth and biomass accumulation.

The increased stand mortality witnessed under no-shade treated plots was as a result of prolonged dry season that led to diminishing soil moisture deficit around the cacao root zone due to direct exposure to sunlight with increased evaporation from the soil surface (Daymond *et.al.,* 2002a). The reduction in stand mortality under moderate and dense shaded plots was traced to improved microclimate conditions occasioned by shade plants that aided reduced air and soil temperature, reduced moisture loss through evaporation and increased activities of microbial organism under shaded microclimate.

More so, the early canopy cover from individual cacao plant under no shade plots may have contributed to reduced moisture loss to the atmosphere via evaporation which thereby helped in soil moisture conservation which thereby increase the amount of available moisture for growth and development. Irrigation may be implicated for the non-significant effects of shade on percent seedling survival at the end of first dry season. Irrigation enhanced soil moisture availability during the dry season. These results were supported by Joly (1988) and Agele *et. al,* (2015) that moisture is the principal requirement for crop survival during the dry season to supplement soil moisture loss due to transpiration, evaporation and diminishing soil water due to dry and hot air.

Soil evaporation decreases proportionally over the growing season as the ground surface is increasingly shaded by the crop canopy. The effect of both crop transpiration and soil evaporation are integrated into a single crop coefficient (Kc) incorporating crop characteristics and average effects of evaporation from the soil' (Kassam & Smith 2001).

Conclusion

It was concluded that cacao field establishment, growth and pod yield will improved significantly if dry season irrigation is provided for the first three years of establishment.

More so, stand mortality as a result of dry season soil moisture deficit in the first, second and third dry season can be avoided through dry season irrigation.

Shade can be considered to ameliorate the cocoa micro-environment.

In terms of optimizing the physiological performance of cocoa, the optimal shade level will depend on how harsh the local climate is.

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Table 1: Effects of shade regimes on percent survival of cacao at the onset and end of dry seasons

Shade	2012/2013		2013/2014		2014/2015	
	Onset of dry season	End of Dry season	Onset of dry season	End of dry season	Onset of dry season	End of dry season
Dense	99.5a	68.2a	68.0a	52.1a	51.0a	48.4a
Moderate	99.9a	60.1a	58.9b	44.2b	44.2b	40.0b
No Shade	100.0a	31.4b	31.4c	27.1c	27.1c	27.1c

Table 2: Effects of shade regimes on percent stand mortality of cacao at onset and end of dry seasons

Shade treatment	2012/2013		2013/2014		2014/2015	
	Onset of dry season	End of Dry season	Onset of dry season	End of dry season	Onset of dry season	End of dry season
Dense	0.5a	31.8b	32.0b	47.9b	49.0b	51.6c
Moderate	0.5a	39.9b	41.1b	55.8b	53.8b	60.0b
No Shade	0.00b	59.6a	68.6a	72.9a	72.9a	72.9a

Table 3: Effects of varying seasons of irrigation on percent stand survival of cacao at onset and end of dry seasons.

Irrigation treatment	2012/2013		2013/2014		2014/2015	
	Onset of dry season	End of dry season	Onset of dry season	End of dry season	Onset of dry season	End of dry season
Three season irrigation	99.8a	99.8a	98.5a	98.5a	98.5a	98.5a
Two season irrigation	99.8a	99.8a	99.8a	99.8a	99.8a	65.4b
One season irrigation	99.5a	99.5a	99.5a	75.2b	75.2b	55.5c

Table 4: Effects of shade regimes and varying seasons of irrigation on percent survival of cacao at the onset and end of dry seasons

Shade Treatment	Irrigation treatment	2012/2013		2013/2014		2014/2015	
		Onset of dry season	End of dry season	Onset of dry season	End of dry season	Onset of dry season	End of dry season
Dense shade	Three seasons irrigation	99.8a	99.8a	99.5a	99.5a	96.5a	98.5a
	Two seasons irrigation	99.8a	99.8a	99.5a	99.5a	99.5a	85.5b
	One season irrigation	99.5a	99.5	99.5a	73.5b	73.0b	54.7c
Moderate shade	Three seasons irrigation	99.8a	99.8a	97.6	97.5a	97.5a	97.5a
	Two seasons irrigation	99.7a	99.7a	99.5a	97.5a	97.5a	83.5b
	One season irrigation	100.0a	100.0	99.0a	73.5b	73.5b	52,5c
No shade	Three seasons irrigation	100.0a	100.0a	99.5a	99.5a	99.5a	99.5a
	Two seasons irrigation	100.0a	100.0a	98.0a	97.0a	97.5a	89.5b
	One season irrigation	100.0a	100,0a	99.0a	77.0b	57.0b	56.5c

Table 5: Effects of shade regimes on percent number of flower and pod bearing stands between 10-18 months after transplanting.

Shade treatment	% number of flower bearing stands in months after transplant						% number of pod bearing stands in months after transplant						
	10	11	12	13	14	15	12	13	14	15	16	17	18
Dense	0.0a	0.0a	0.0a	2.0a	2.2a	5.4a	0.0a	0.0a	0.0b	3.3a	3.7a	5.4a	15.1a
Moderate	0.0a	0.0a	0.0a	3.1a	4.1a	8.2a	0.0a	2.4a	3.6a	5.3a	5.2a	6.6a	17.3a
No Shade	0.0a	0.0a	0.0a	0.0b	0.0b	2.1b	0.0a	0.0a	0.0b	1.5b	2.2b	2.7b	3.0b

Table 6: Effects of varying seasons of irrigation on percent number of flower and pod bearing stands between 10-18 months after transplanting

Irrigation treatments	% number of flower bearing stands in months after transplant						% number of pod bearing stands in months after transplant						
	10	11	12	13	14	15	12	13	14	15	16	17	18
Three seasons irrigation	0.0b	6.3a	20.4a	69.3a	100a	100a	6.2a	13.1a	30.4a	45.0a	65.a	95a	100a
Two seasons irrigation	2.1a	5.4a	16.1ab	60.2a	100a	100a	3.1a	10.2a	25.2a	30.1b	60a	92a	100a
One season irrigation	2.3a	5.1a	16.3ab	60.1a	100a	100a	5.3a	10.0a	27.3a	37.7a	55b	90a	95a

Table 7: Effects of shade regimes and varying seasons of irrigation on percent number of flower and pod bearing stands between 10-18 months after transplanting

Irrigation treatments	Shade treatments	% number of flower bearing stands in months after transplant						% number of pod bearing stands in months after transplant						
		10	11	12	13	14	15	12	13	14	15	16	17	18
Dense shade	Three seasons irrigation	0.0b	0.0b	3.5c	8.2b	8.5c	16.0b	0.0b	0.0c	2.4b	2.4c	10.3b	16.0b	25.8b
	Two seasons irrigation	0.0b	0.0b	5.4b	6.0c	12.8b	17.1b	0.0b	0.0c	0.0c	2.2c	11.6b	18.5b	26.3b
	One season irrigation	0.0b	0.0b	3.2c	6.1c	9.6c	14.3b	0.0b	0.0c	0.0c	5.0b	7.3c	15.2b	21.2b
Moderate Shade	Three seasons irrigation	0.0b	5.1a	8.6b	8.5b	16.2b	21.3b	0.0b	3.2b	3.2b	7.3b	14.2b	19.5b	29.0b
	Two seasons irrigation	5.1a	7.3a	7.3b	10.3b	19.4b	23.3b	2.2b	5.4b	7.3b	10.5b	13.4b	23.0b	32.1b
	One season irrigation	3.3a	10.5a	10.1b	10.3b	15.2b	21.5b	0.0b	3.1b	5.1b	8.2b	16.9b	21.1b	26.4b
No shade	Three seasons irrigation	0.0b	9.2a	15.1a	60.0a	76.4a	95.4a	7.2a	9.3a	20.3a	35.2a	69.2a	85.4a	98.5a
	Two seasons irrigation	0.0b	5.4a	13.3b	51.7a	70.5a	89.0a	6.5a	10.6a	24.2a	50.4a	75.1a	92.2a	100.1a
	One season irrigation	0.0b	5.4a	25.4a	55.4a	68.3a	96.1a	8.2a	10.3a	29a	46.5a	79.5a	96.0a	100.2a

Table 8: Effects of shade regimes on pod yield during the peak and off season

Shade treatment	Pod yield in months after transplant								
	15	16	17	18	19	20	21	22	23
Dense	7.2b	12.0b	12.0b	5.3b	2.0b	0.0a	0.0a	0.0a	5.2a
Moderate	13.4a	15.2ab	16.0b	7.8a	1.0b	0.0a	0.0a	0.0a	4.0a
No Shade	17.4a	22.5a	29.5a	11.5a	5.0a	0.0a	0.0a	0.0a	2.1b

Table 9: Effects of varying seasons of irrigation on pod yield during the peak and off season

Shade treatment	Pod yield in months after transplant (Peak season)				Pod yield in months after transplant (off season)				
	15	16	17	18	19	20	21	22	23
Three seasons irrigation	16.4a	17.5a	22.6a	24.0a	4.2a	0.0a	6.1a	14.5a	16.0a
Two seasons irrigation	19.2a	20.0a	26.1a	26.1a	1.8a	0.0a	4.6a	11.3a	15.5a
One season irrigation	14.0a	16.5a	21.5a	23.9a	3.0a	0.0a	0.0b	0.0b	0.0b

Table 10: Effects of shade regimes and varying seasons of irrigation on on-season and off-season pod yield in cacao.

Irrigation treatments	Shade treatments	Average number of pod per stand per treatment in months after transplant											
		July	Aug	Sept.	Oct.	Nov.	Dec.	Jan	Feb.	Mar	April	Oct	Dec
Dense shade	Three seasons irrigation	6.5a	7.3b	8.6b	9.0c	13.0b	6.0b	2.3b	0.0b	3.7a	11.5a	20b	35b
	Two seasons irrigation	5.5a	6.7b	8.5b	11.2b	12.5b	7.3ab	3.5a	1.2a	5.6a	13.2a	22b	37b
	One season irrigation	2.4c	5.5b	7.8b	8.0c	10.1b	5.5b	0.0c	0b	0.0b	0.0c	12c	24c
Moderate Shade	Three seasons irrigation	6.6a	7.0b	8.5b	11.0b	13.3b	6.4b	3.0ab	2.0a	3.0a	15.1a	27b	46b
	Two seasons irrigation	4.8ab	6.0b	8.8b	10.4b	12.8b	6.6b	2.0b	1.0a	3.2a	12.3a	23b	42b
	One season irrigation	4.2b	5.8b	7.9b	11.7b	13.4b	5.0b	1.5b	0.0b	0.0b	1.3b	13c	20c
No shade	Three seasons irrigation	7.5a	10.2a	13.2a	18.3a	22.9a	9.0a	4.5a	3.5a	3.5a	17.8a	45a	65a

	Two seasons irrigation	8.3a	12.8a	17.1a	22.4a	27.9a	7.2ab	2.5ab	3.0a	2.5a	14.0a	43a	70a
	One season irrigation	2.2c	11.4a	20.0a	26.2a	27.1a	6.1b	0.0c	0.0a	0.0b	0.0c	14c	28c