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Influence of Seasonal Variations and Photoperiodism on Growth Phases and Crop Cycles in Selected Rice (*Oryza sativa*) Genotypes Grown in Southern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors UGM and UW wrote the draft of the manuscript. All authors participated in the field experiment. Authors UGM, ENE and ACC did the statistical analysis. All authors proof read the manuscript.

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ABSTRACT

Aim: To investigate the influence of seasonal variations and photoperiodism on the growth phases and cropping cycles of selected rice genotypes in Nigeria
Study Design: The study was a 2 factor factorial experiment laid out in a randomized complete block design (RCBD) with three (3) replicates.
Place and Duration of Study: The trial studies was carried out in four locations, Adim, Assiga, Idomi and Ofodua in 2014 and 2015 crop growing seasons.
Methodology: The experiment for seasonal variation effect was carried out in the field while the experiment on photoperiodism effect was carried in the screen house at Adim. The experiment was a 2 factor experiment. Factor 1 was the rice genotypes which had 4 levels (FARO 44, FARO 12, FARO 15 and FARO 55) while factor 2 which was the different locations also had four levels (Adim,

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Assiga, Idomi and Ofodua). The experiments were laid out in a randomized complete block design (RCBD), replicated three times with intra and inter – row spacing of 15x15 cm. Plot size of 25 x20 m, was maintained with sampling area of 2 m^2. For the natural day length, three seedlings were transplanted into the polyethylene bags containing about 5 kg of soil later thinned to two plants and fertilized with 1g of N, P_2O_5 and K_2O because the initial soil analysis results showed low values of the soil nutrients. The soils were flooded throughout the growth of plants. The experiment for photoperiod was carried out at the World Bank Assisted Rice project in Adim in June, 2014. Three 7 - day old seedlings were transplanted to each polyethylene bag containing 5 kg of soil and fertilized with 2 g each of N, P_2O_5 and K_2O. The plants were subjected to 8, 10, 12, 13, 14 16 and 24 h photoperiods, in a 24 h cycle. The experiment was terminated after 200 days. Their response to different photoperiod treatments were investigated with rice plants in polyethylene bags subjected to varying lengths under artificial light.

Results: High photoperiod - sensitive varieties, showed significant ($p<0.05$) difference in their maturation periods (crop cycle) when planted at different times (seasons) of the year. The results showed significant ($p<0.05$) differences in growth phases and crop cycles in the various genotypes as influenced by seasons and photoperiod. The results showed that total growth phase (BVP and PSP) was 86 d for FARO 44 and >130 d for FARO 15. The longest crop cycle of 249 d occurred when plantings were made in January – February with FARO 15 while shortest crop cycle of 78 d occurred when plantings were made in the October - November with FARO 44. In some of the photoperiod - sensitive varieties, exposure of the rice genotypes for 10 h yielded the shortest crop cycle and growth phases for FARO 44 while exposure of varieties to longer photoperiods of 24 h yielded the longest crop cycles for all the varieties when planted in the same month, of different years. These varieties would be unsuitable for planting during the off season (August to September). The results are discussed in light of photoperiod sensitivity of some rice varieties planted at different times of the year.

Conclusion: The results of the study have shown that growth phases and crop cycle of any rice variety is determined by the length of the vegetative reproductive and ripening phases. Since the duration of reproductive and ripening phases is very essential to the crop, it is the vegetative phase that differs and determines the crop cycle of the rice variety. In this test, the crop cycles of Faro 44 and Faro 12 did not vary much with different photoperiods. These test crop varieties (Faro 44 and Faro 12) contrast strongly with those of Faro 52 and Faro 15, in terms of the seasonal variations and photoperiodic screening. The study has been able to bridge the gap in knowledge on seasonal variations and photoperiodism and how these influence rice growth and production in this agro-ecology.

Keywords: Photoperiod sensitive phase; growth duration; Oryza sativa; basic vegetative phases.

1. INTRODUCTION

The need for increasing food production to meet the teaming population of the country has become imperative now than ever. The continued drift of the population from the rural to urban areas in search of other economic pursuits to the neglect of agriculture portends danger in the nearest future. Again, Nigeria food bill import is growing daily and this exert negative implication on Nigeria foreign reserve and food security [1].

In realization of this, the current Government placed an embargo on importation of some food items including rice in other to boast potential income generation for domestic rice farmers, encourage domestic food and rice production with a view to enhance agricultural activities and ensure good living standard for her citizenry [2].

Rice *(Oryza sativa)* is the most important of the world's cereals and forms the basis for the home diet of millions of people in South-east Asia, America, Europe and Africa. In fact, it forms the staple food for more than 50% of the world's population and remains one of the oldest grown crop in history [3].

Rice (*Oryza sativa*) has its origin from Asia while *Oryza glaberrima* is of West African origin [4].

Rice is cultivated through seeds. Early wet or dry nursery establishment for sprouting of seeds is the common production practice to meet with improved varieties [5].

Rice is planted in April – May in nursery and transplanted in June-July to the field. Fertilizers such as Superphosphate or sulphate of ammonia fertilizer are broadcast at 130 kg/ha in nursery. For optimum yield, ammonium sulphate is usually applied 5-10 cm deep in soil before flooding or irrigation commences [6].

Rice do well in a wide range of ecology. Rainfall of 1250 – 1500 mm spread in at least four months of cultivation is ideal. Rice can also do very well in areas of high humidity and temperature. Swamp rice prefers flooded conditions but it is not adequate because it prevent aeration while the upland rice prefers well drained soils under humid condition [7].

Rice do well or requires a rich loam to clayey soil, retentive to water and rich in humus. Rice can be grown practically on all types of soils provided there is water. Rice is ready for harvesting when the grains dry and becomes hard around August to November depending on whether it is late or early rice and on variety cultivated. Harvesting is done manually using sickles or mechanically by using combine harvesters by removal of the panicle of grains [8].

Rice is used as staple food, as raw material for industries and as livestock feed as well as a source of starch [9].

In Nigeria, rice is planted in lowland and upland regions. Upland rice depends on rainfall or irrigation or is planted as swamp rice in water logged soils or submerged land [9].

In the Southern part of Nigeria where there are few or no irrigation facilities, rice is grown once a year. The growth duration and photoperiod sensitivity of the rice varieties cultivated may therefore appear relatively unimportant. Jagoe and Larter [10] found that some of the Nigerian rice varieties are photoperiod sensitive (day light dependent). The differences on maturation periods (crop cycle) when planted at different dates (seasonal variations) are governed by the prevailing day length. Van [11] suggested that work on the selection of photoperiod - sensitive varieties of rice was very important in determining the growth duration (growth phases) of rice varieties in relation to the prevailing day length.

Work on this aspect of crop improvement is scanty, especially study in the area that is related to the commonly grown rice varieties in Cross river State, Nigeria. Thus, knowledge of the growth duration of both photoperiod - sensitive and insensitive varieties of rice under field and controlled condition is necessary. An explanation for the growth duration pattern when planted in different months or season is desirable. This study was carried out with the objective of estimating the growth phases, duration and crop cycles of some Nigerian rice varieties as to determine the best season and photoperiod for greater crop yield.

2. MATERIALS AND METHODS

2.1 Location of Experiment

The experiments were carried out simultaneously at four localities in cross river state, namely: Adim, Idomi, Assiga and Ofodua. The four locations are within longitude 8° 03° to 8° 17E° and Latitude 5° 38° to 5°, 59° N. The main rainfall in most of the experimental area is 2500mm with a range of (2250 to 1700mm). Mean daily minimum and maximum temperatures vary from 21^{o}c to 24°c and 27° to 32° respectively. Relative humidity varies from 82 to 97% [12].

The source for the planting materials was the National Cereal Research Institute (NCRI) Badegi, Niger State. The rice varieties were: Faro 12, Faro 15, Faro 44 and Faro 52.

The experiments were laid out in a randomized complete block design (RCBD), replicated three times with intra and inter – row spacing of 15x15 cm. Plot size of 25 x20 m, was maintained with sampling area of 2 m^2.

For the natural day length, three seedlings were transplanted into the polyethylene bags containing about 5 kg of soil later thinned to two plants and fertilized with 1g of N, P_2O_5 and K_2O because the initial soil analysis results showed low values of the soil nutrients. The soils were flooded throughout the growth of plants.

The experiment for photoperiod was carried out at the World Bank Assisted Rice project in Adim in June, 2014. Three 7 - day old seedlings were transplanted to each polyethylene bag containing 5 kg of soil and fertilized with 2 g each of N, P_2O_5 and K_2O. The plants were subjected to 8, 10, 12, 13, 14 16 and 24 h photoperiods, in a 24 h cycle. The experiment was terminated after 200 days. The obtained data was subjected to analysis of variance (ANOVA) and means were compared using fishers least significant different at 5% probability level, using the methods of Obi [13]. The Genstat software was used to analyze statistical data generated therein.

3. RESULTS

In the photoperiod experiment, the two varieties which showed high variation in growth phases in the field also showed high photoperiod sensitivity. The turning points for these varieties were less than 12 h. The turning point is defined as the minimum photoperiod longer than 10 h, was found to definitely prolong the growth phases (in terms of basic vegetative phases and photoperiod sensitive phase) of Faro 52 and Faro 15, which were greater than 136 days and there was no flowering (Table 1 and Fig. 1). The variations observed in the basic vegetative phases of growth among the rice varieties were strongly influenced by the time of planting and photoperiods. Faro 44 variety tends to attain this period earlier than the other varieties under the same conditions. It was closely followed by faro 15 and faro 12 which had basic vegetative growth phases of 30 and 32 d respectively. The longest basic vegetative phase was observed in Faro 52 which required 53 d to attain and complete this phase. The basic vegetative phase of growth in rice is a period of high physiological and biochemical processes in the plant tissues preparing the crop plants for the next phase of growth which is grain formation and filling. This may more likely be influenced by availability of nutrients, crop variety, management practices and pest and diseases. Therefore, it is a period where much attention should be given to the crops to ensure the full realization of its productive potentials.

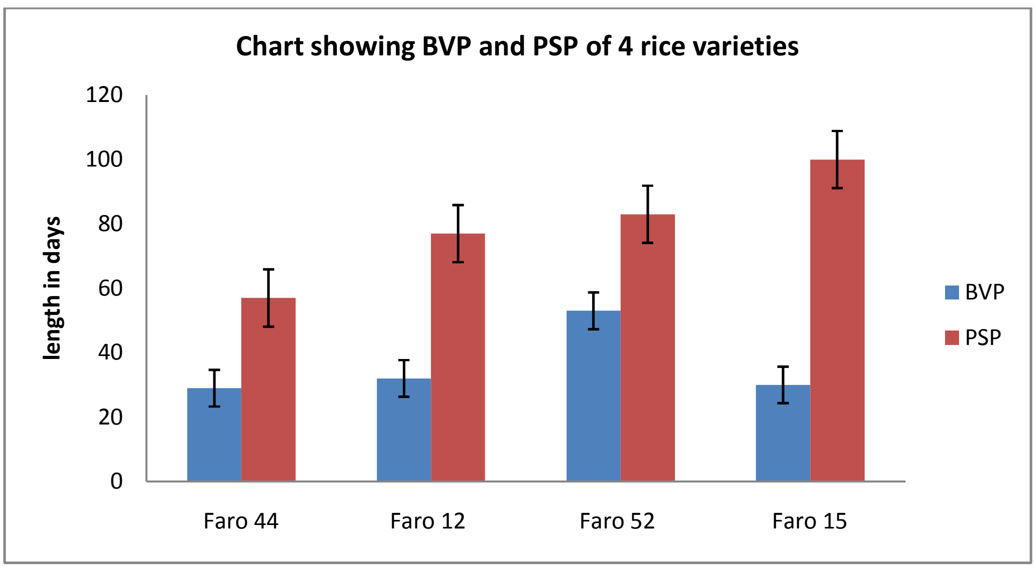

Fig. 1. BVP and PSP of 4 rice varieties

Table 1. Basic vegetative phase and photoperiod sensitive phases (Growth phases) of growth of 4 rice varieties as influenced by seasonal variation and photoperiods in (days)

	BVP	PSP	Total growth phase (BVP + PSP)
Faro 44	29	57	86
Faro 12	32	77	109
Faro 52	53	83	136
Faro 15	30	>100	>130
LSD (0.05)	3.07*	10.92*	

BVP = Basic Vegetative Phase (earliest flowering minus 35 days)
PSP = Photoperiod-sensitive phase (difference between earliest and lastest flowering per variety)

The photoperiod sensitive growth phase highly influences the reproductive stage of the crops. Varieties that are photo-sensitive make the maximum use of light to develop and fill their grains at a faster rate, while the photoperiod insensitive varieties will develop and fill their grains at all times but gradually or at slow rate.

Table 2 and Fig. 2 shows photoperiod of four rice varieties from sowing to flowering with day length indicated in hours. At day length of 8 h Faro 12 and 15 had flowering days of 67 and 66 respectively. The Faro 44 and Faro 52 had 72 and 106 d respectively. Increasing the number of hours from 8 to 10 did not show any significant different in terms of number of hours. When the numbers of hours were increased from 12 to 16 h, there was a consistent increase in number of days from sowing to flowering (growth phases). When it was further increased from 16 to 24 h there were 7.0% drop in days in Faro 44, 5.9% in Faro 12 and 2.0% in Faro 52 during the study period.

Table 3 and Fig. 3 shows growth phases (days from sowing to flowering of one rice variety planted at four locations (Faro 44). The values of growth duration for Faro 44 for 2014 and 2015 vary from one location to another, from January to December. The following days ranged as follows: 71-91 for Adim and Ofodua; 71-94 for Idomi; 80-91 for Assiga.

Differences between locations in terms of days from sowing to harvesting of Faro 44 variety were statistically significant ($p<0.5$). However, values for Assiga and Ofodua for February, March, April, July, September. October and December tended to be similar in 2014 (Table 4). There were no variations in values of certain months in 2015 from April to June then September and December.

Table 2. Crop cycles of 4 rice varieties as influenced by photoperiodic screening in hours

	8	10	12	13	14	16	24
Faro 44	72	64	80	112	119	121	113
Faro 12	67	67	89	86	123	144	136
Faro 52	106	88	116	146	153	171	168
Faro 15	66	65	80	NF	NF	NF	NF
Mean	78	71	91	115	132	145	139

NF = No flowering after 200 days

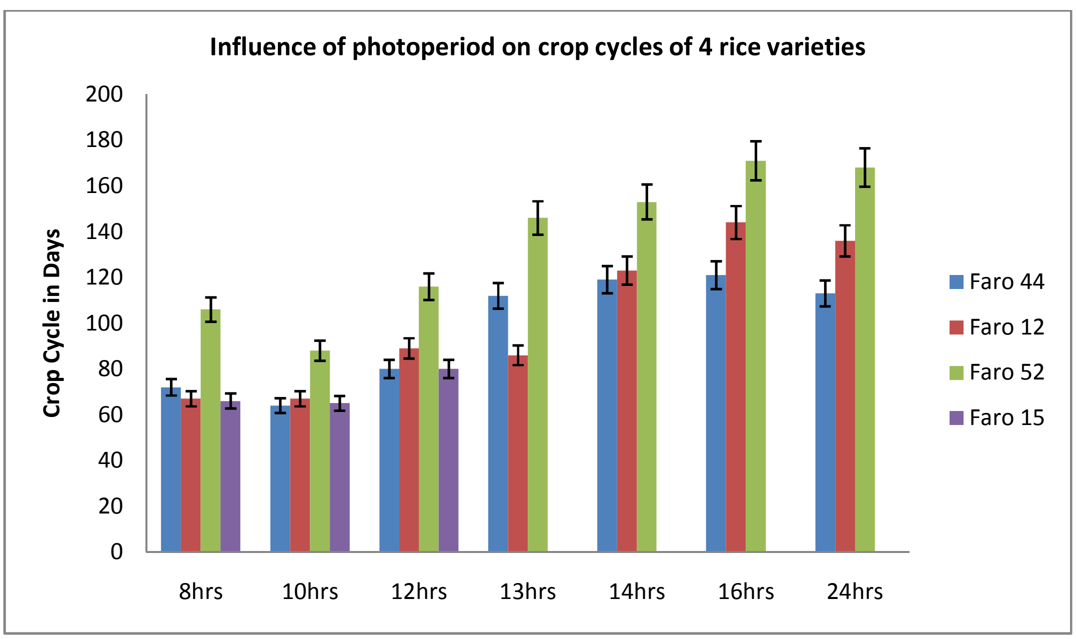

Fig. 2. Influence of photoperiod on crop cycles of 4 rice varieties

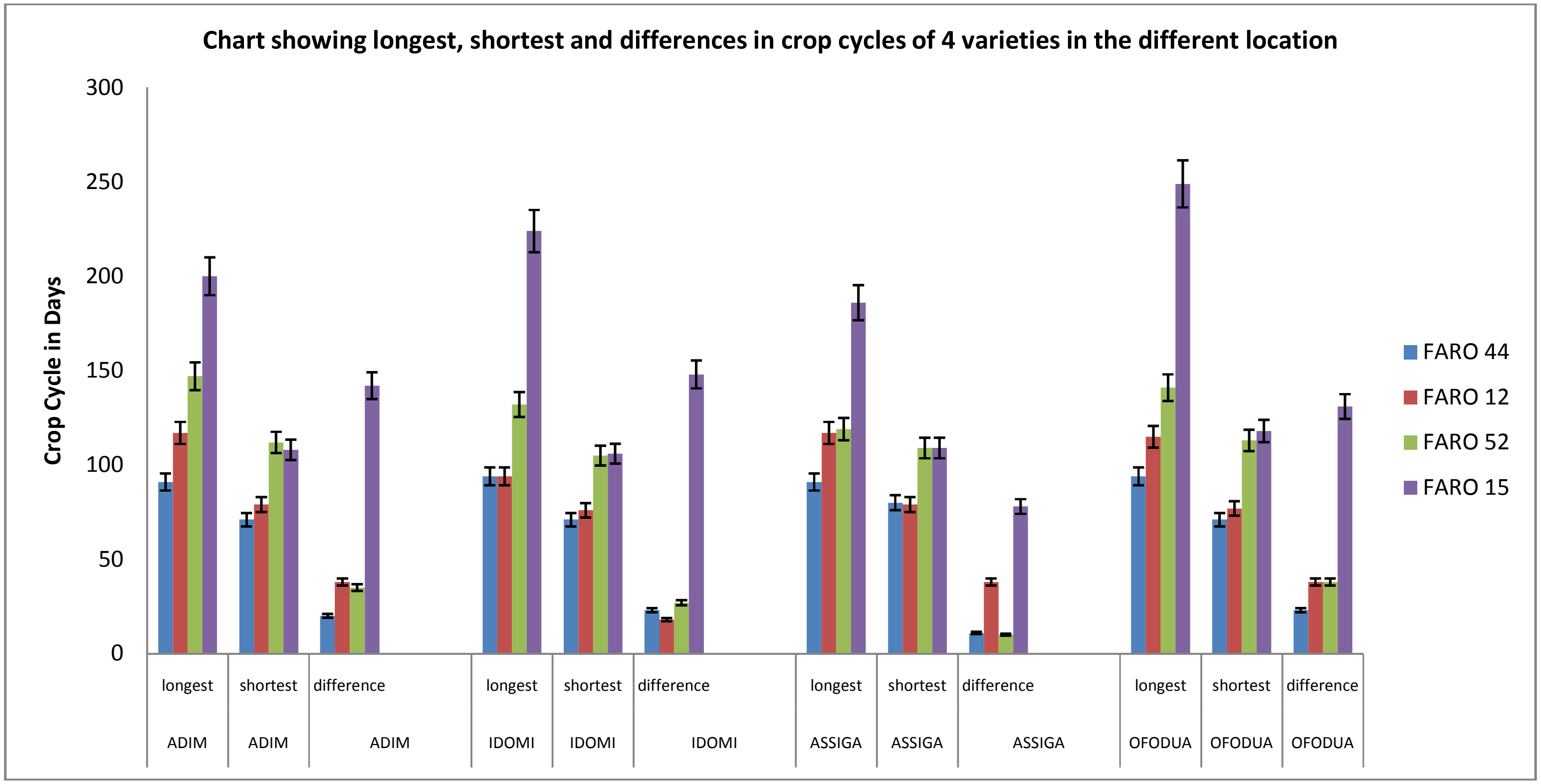

Fig. 3. Longest, shortest and differences in crop cycles of 4 rice varieties at different locations

Table 3. Longest, shortest and differences in crop cycles of rice varieties as influenced by seasonal variations and photoperiod exposures

Duration	Faro 44	Faro 12	Faro 52	Faro 15	Location
Longest	91	117	147	200	Adim
Shortest	71	79	112	108	Adim
Difference	20	38	35	142	Adim
Longest	94	94	132	224	Idomi
Shortest	71	76	105	106	Idomi
Difference	23	18	27	148	Idomi
Longest	91	117	119	186	Assiga
Shortest	80	79	109	109	Assiga
Difference	11	38	10	78	Assiga
Longest	94	115	141	249	Ofodua
Shortest	71	77	113	118	Ofodua
Difference	23	38	38	131	Ofodua

Table 4. Crop Cycles (days from sowing to harvesting) of Faro 44 rice variety planted at different dates in the at different localities

Variety: Faro 44

Month	Years	Locations				
		Adim	**Idomi**	**Assiga**	**Ofodua**	**LSD (0.05)**
January	2014	91	94	81	89	3.0
	2015	86	94	83	88	3.3
February	2014	87	93	85	85	4.0
	2015	89	93	86	91	3.0
March	2014	83	91	87	88	5.0
	2015	91	88	84	88	4.1
April	2014	86	94	91	90	3.0
	2015	89	84	89	90	5.0
May	2014	86	91	89	94	3.3
	2015	89	71	88	90	3.0
June	2014	87	87	89	93	3.0
	2015	86	85	82	84	3.2
July	2014	92	94	88	89	7.5
	2015	86	87	84	90	4.5
August	2014	81	96	`86	93	3.1
	2015	81	86	84	71	6.0
September	2014	81	82	86	86	3.0
	2015	80	78	84	84	4.2
October	2014	80	75	84	84	6.1
	2015	75	78	85	82	5.0
November	2014	79	89	84	94	5.4
	2015	71	78	86	80	4.8
December	2014	88	83	84	83	3.6
	2015	80	83	80	80	3.0
Longest		91	94	91	94	
Shortest		71	71	80	71	
Differences		20	23	11	23	

Table 5 shows values of Faro 12 on growth duration for four locations in which values ranged as follows:- 79-114 for Admin, 76-94 for Idomi, 79 – 117 for Assiga and 74 – 118 days for Ofodua during the 2014 and 2015 planting seasons. Differences between locations in terms of growth duration were significant ($p<0.05$), from January to December in 2014 and 2015 planting seasons. The mean values were higher from February to July for Adim and Ofodua. The average mean values tended to decrease in the four locations from August to December and the decrease followed a similar pattern.

Table 5. Crop Cycles (days from sowing to harvesting of Faro 12 rice variety planted at different dates in the at different localities

Variety: Faro 12

Month	Years	Locations				
		Adim	Idomi	Assiga	Ofodua	LSD (0.05)
January	2014	90	79	104	90	9.2
	2015	83	82	102	92	8.3
February	2014	99	82	90	101	9.0
	2015	106	87	80	114	7.0
March	2014	104	82	94	112	11.1
	2015	117	86	92	115	5.8
April	2014	111	90	102	108	5.7
	2015	113	87	101	118	5.0
May	2014	112	91	99	115	7.2
	2015	114	92	117	114	16.4
June	2014	109	90	82	106	6.8
	2015	103	90	103	103	12.1
July	2014	111	94	93	103	9.6
	2015	103	88	104	97	6.0
August	2014	93	87	97	94	9.0
	2015	90	85	91	85	4.8
September	2014	82	83	79	77	3.0
	2015	80	85	90	74	4.7
October	2014	81	76	97	77	4.0
	2015	85	81	94	80	4.0
November	2014	80	83	89	90	5.4
	2015	79	86	90	78	5.3
December	2014	88	83	93	84	4.0
	2015	79	83	89	90	4.0
Longest		117	94	117	115	
Shortest		79	76	79	77	
Differences		38	18	38	38	

The results of growth duration of variety Faro 52 planted at four locations is presented in Table 6, in which the highest crop cycle of 199 days was recorded in May 2014 at Assiga while the lowest, 105 in September was recorded in Idomi location. The implication here is that Faro 52 variety had delayed flowering in the four locations than either Faro 12, or Faro 44.

However, differences in mean values between the four locations were significant ($p<0.05$) throughout the experimental seasons.

Table 7 shows the growth duration values of Faro 15, in four study locations in which the highest (250 days) occurred in February 2015 at Adim while the lowest (106 days) occurred in October 2015 at Idomi. Days from sowing to flowering of this variety showed greater values in 2014 planting, on the average than 2015 planting. Equally, these values showed that Faro 15 variety delayed flowering at different planting dates and locations more than Faro 12 and Faro 44 varieties throughout the study season.

4. DISCUSSION

The existing Nigerian rice varieties can be divided essentially into two groups; those that are highly photoperiod sensitive and those that are weakly photoperiod - sensitive. The flowering of highly photoperiod sensitive varieties (classified as season - fixed) represented by Faro *52,* was greatly delayed by a small increase in length of the photoperiod. At certain photoperiods no flowering was obtained even after 200 days of growth, [14]. The weakly photoperiod - sensitive varieties (Period - Fixed) such as Faro 15 and Faro 52 showed very little variation in crop cycles under field conditions, but were delayed in flowering when subjected to long photoperiods (12-16 hours). The delay however was not as great as the highly photoperiod - sensitive verities, (Tables 4-7).

Table 6. Crop Cycles (days from sowing to harvesting) of Faro 52 rice variety planted at different dates in the different localities

Variety: Faro 52

Month	Years	Locations				
		Adim	Idomi	Assiga	Ofodua	LSD (0.05)
January	2014	121	126	112	125	5.0
	2015	131	130	118	118	10.2
February	2014	119	130	117	125	5.0
	2015	130	131	119	136	12.6
March	2014	123	125	118	118	6.4
	2015	128	132	117	141	8.8
April	2014	124	122	199	128	7.9
	2015	147	127	118	121	7.6
May	2014	124	122	199	128	4.0
	2015	147	127	118	121	18.5
June	2014	120	116	116	127	6.2
	2015	128	125	118	123	4.0
July	2014	126	128	115	127	9.8
	2015	125	120	117	128	7.3
August	2014	114	114	112	122	7.7
	2015	118	112	112	125	5.1
September	2014	117	111	113	119	4.0
	2015	119	105	110	119	5.0
October	2014	117	115	113	123	4.5
	2015	115	108	111	121	6.1
November	2014	112	116	109	118	4.0
	2015	112	115	109	113	4.0
December	2014	112	122	112	115	6.3
	2015	121	121	112	115	6.2
Longest		147	132	119	141	
Shortest		112	105	109	113	
Differences		35	27	10	38	

Although the results of the experiments tend to show that sensitivity to photoperiod is the factor determining the growth phases and crop cycles, it is not the only factor. Crop cycle of any variety is determined by the length of the vegetative reproductive and ripening phases. Since the duration of reproductive and ripening phases are essential to crop development, it is therefore the vegetative phase that differs and determines the growth duration or crop cycle of the variety [15]. Two varieties that were photoperiod -insensitive were Faro 44 and Faro 12, although the growth duration of Faro 12 is longer than Faro 44, both varieties showed very little variation in growth phases with different photoperiods [16,17,18].

The test varieties Faro 52 and Faro 15, which were considered as “period fixed” and their curves, contrast strongly with those of Faro 44 and Faro 12. The relative short crop cycle of Faro 44 was mainly the result of high temperature [19]. Varieties that do not flower or take longer than 200 days to flower at 13 hours, will be sensitive to day length changes in Cross River State, Nigeria.

An interesting observation made in the field experiments was the great difference in crop cycles of the highly photoperiod sensitive varieties, planted in the same month not in different year. It is suggested in this study that cloudiness may have something to do with this big difference in photoperiod sensitivity of Faro 12 and Faro 44.

A small difference in day length may cause a great delay in the crop cycle of a photoperiod - sensitive variety. It was found that cloudy weather in the early and late part of the day shortens the twilight hour, and hence, the effective day length.

A difference of 30-40 days in growth duration as a result of cloudiness has been reported [20].

Table 7. Crop Cycles (days from sowing to harvesting) of Faro 15 rice variety planted at different dates in the different localities

Variety: Faro 15

Month	Years	Locations				
		Adim	Idomi	Assiga	Ofodua	LSD (0.05)
January	2014	210	249	148	213	34.2
	2015	211	244	136	184	32.6
February	2014	249	249	186	232	49.8
	2015	250	236	163	249	12.5
March	2014	233	122	182	227	55.6
	2015	224	120	161	226	36.1
April	2014	212	199	165	205	32.6
	2015	212	192	163	194	9.2
May	2014	182	184	156	178	25.3
	2015	188	181	150	174	23.3
June	2014	162	123	147	163	16.9
	2015	158	124	140	151	6.0
July	2014	146	142	139	148	6.0
	2015	139	135	141	142	5.0
August	2014	119	123	120	131	4.0
	2015	121	120	119	125	4.0
September	2014	112	125	118	123	5.2
	2015	117	108	115	199	5.0
October	2014	117	120	116	125	4.0
	2015	110	106	108	119	4.0
November	2014	108	112	115	124	4.0
	2015	108	121	111	118	6.5
December	2014	124	132	124	129	5.1
	2015	132	124	116	130	7.2
Longest		200	224	186	249	
Shortest		108	106	109	118	
Differences		142	143	78	131	

5. CONCLUSION

The results of the study have shown that growth phases and crop cycle of any rice variety is determined by the length of the vegetative reproductive and ripening phases. Since the duration of reproductive and ripening phases is very essential to the crop, it is the vegetative phase that differs and determines the crop cycle of the rice variety. In this test, the crop cycles of Faro 44 and Faro 12 did not vary much with different photoperiods- These test crop varieties (Faro 44 and Faro 12) contrast strongly with those of Faro 52 and Faro 15, in terms of the seasonal variations and photoperiodic screening. The study has also been able to increase the available literature on the subject matter on these varieties which have been very scanty. This will in addition, help to promote increase yield of rice if adopted by farmers in this agro-ecology conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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