



CLIMATE CHANGE AND VARIABILITY FARM-LEVEL ADAPTATION STRATEGY FOR SUSTAINABLE SOYBEAN PRODUCTION IN RAINFOREST AGRO-ECOLOGY, NIGERIA

Adetayo, A. O.

Department of Water Resource Management and Agrometeorology, Federal University
Oye Ekiti, Ekiti State, Nigeria

Corresponding Author's Email: wale_agromet@yahoo.com, **GSM:** 08058976504

ABSTRACT

Field experiments were conducted during the 2021 and 2022 planting seasons at the Laboratory for Geo-ecology and sustainable food systems, Federal University of Technology Akure and Institute of Agricultural Research and Training Ibadan. Both locations are within the rain-forest agro-ecological zone of Nigeria. The varieties of soybean used are, IT1498 (V1), IT1951 (V2) and TGX1448-2E (V3). The three planting dates selected for are 28th April, 12th of May and 26th of May in 2021 and 16th April, 30th of April and 14th of May in 2022. Cultivar differences were noticed among the three varieties soybean which indicated their generic differences. Generally, the growth and yield parameters of soybean decreased with delayed planting irrespective of the variety, locations and year of planting. The average yield of soybean reduced with delayed planting as 1821.34 kg ha⁻¹, 1663.67 kg ha⁻¹ and 1504.0 kg ha⁻¹ from planting dates 1 to 3 respectively. Yields of Soybean planted in Ibadan was more (1671.99 kg ha⁻¹) than those in Akure (1654.16 kg ha⁻¹). Planting season on the other hand, 2021 produced more yield of soybean (1665 kg ha⁻¹) than 2022 (660 kg ha⁻¹). Among the soybean varieties, IT1498 had the highest yield (1716.31 kg ha⁻¹), followed by IT1951 (1649.55 kg ha⁻¹) and TGX1448-2E (1623.38 kg ha⁻¹). Farmers are advised to Plant soybean at the onset of rains for optimum yield of the crop.

Keywords: Planting, Date, Strategy, Yield, Climate, Change.

INTRODUCTION

Climate change poses a serious threat to people worldwide and impacts their livelihood to varying degrees. Studies revealed that the most vulnerable people belong to developing countries and more precisely rural communities and resource poor farmers. The changing climate is adversely affecting the productivity and livelihoods of Nigerian rural farmers as agricultural productivity in Nigeria has recently experienced declines (Ayoade, 2004). Soybean designated as 'miracle bean' has established its potential as an industrially vital and viable oilseed crop in many areas of the world. Soybeans contain approximately 40% protein and 20% oil on a dry matter basis. The oil is used primarily in edible products such as margarine, cooking oil, and industrially in such products as high-grade paints and pharmaceuticals. The soybean oil meal that remains after the oil is extracted is almost all used as a high protein livestock feed but the meal can be further refined to give various protein extracts for direct human consumption (Ahmed and Hartel, 2019).

Declining agricultural productivity as a result of climate change is worrisome and calls for a great concerned. Militating against the climate change requires knowledge of effectiveness of the coping strategies. Hence the effect of climate change on notable food crop like soybean which has long term implication for food security needs to be investigated (Chaudry, 2014). Most of the farmers in forest-savannah agro-ecological region of Nigeria lack adequate knowledge of climate smart agriculture and sustainable farm management strategies which in turn increased their vulnerability to climate change impacts. Because of the late onset, early cessation of rains and consequent length of growing season, shift in the planting dates of soybean as well as the adaptability of the crop to the ecosystem needed to be investigated. Understanding soybean responses to projected climate change and variability is required for derivation of adaptation strategies for sustainable crop production improvement Shegro *et al.* (2020). Therefore, there is a need to adequately synchronize planting time of soybean to the rainfall pattern at present climate change and variability. For optimum production of soybean, seed must be sown on proper time. The objective of this



study is to investigate the effects of planting date on growth and yield of soybean as farm level adaptation strategy to the impacts of climate change and variability vis-a-vis sustainably maximizing yield potential of soybean.

MATERIALS AND METHODS

Study Area

The research was conducted during the growing season of 2021 and 2022 at Agrometeorology research farm of the Federal University of Technology Akure, Nigeria ($7^{\circ}15'N$, $5^{\circ}15'E$) and project farm of the Institute of Agricultural Research and Training (I.A.R&T.) Ibadan, Nigeria ($7^{\circ}22'N$; $30^{\circ}30'E$). Both stations are within the forest-Savannah eco-climatic zone of Nigeria. The area has distinct wet and dry seasons with mean annual rainfall ranging from 1,150 to 2,500 mm. It is characterized by minimal fluctuations, usually less than $5^{\circ}C$ throughout the year. The mean monthly temperature ranges between $28^{\circ}C$ and $35^{\circ}C$ for the period of 10 years, while the mean monthly minimum temperature ranged between $22.6^{\circ}C$ and $26.7^{\circ}C$. February and March have the highest evaporation rate, and it is as high as 6.9 mm. The least evaporation rate (1.6 mm) is recorded in June/July. The relative humidity ranges from 64.5% in February to 91% in June.

Treatment, Experimental Design and Data Analysis

The treatments consisted of 3 varieties of soybean. The experiment was laid out in split plot design with varieties of crops as the main plot and dates of planting as subplot treatment. The treatment combinations were replicated 3 times in each location. Soil sampling was carried out before land preparation to quantify the baseline nutrient status of the soil before the trial. The result of the pre-planting soil analysis indicates soil pH of 4.76 and 5.12 for Akure and Ibadan respectively. The percentage organic matter and organic carbon of the soils in Akure and Ibadan are 13.2%, 1.28% and 8.9%, 1.04% respectively. The exchangeable bases Ca ($1.50 \text{ cmol kg}^{-1}$) and cation exchange capacity ($3.26 \text{ cmol kg}^{-1}$) was found in Akure soil, while Ca ($1.52 \text{ cmol kg}^{-1}$) and cation exchange capacity ($4.02 \text{ cmol kg}^{-1}$). The textural class of the soil in both sites is sandy-loam.

Minimum tillage was employed as a means of soil-water conservation. The varieties of soybean used are, IT1498 (V1), IT1951 (V2) and TGX1448-2E (V3). The recommended planting space (20cm x 75cm) of the crop was followed. The three planting dates selected for are 28th April (D1), 12th of May (D2) and 26th of May (D3) in 2021 and 16th April (D1), 30th of April (D2) and 14th of May (D3) in 2022 in both locations.

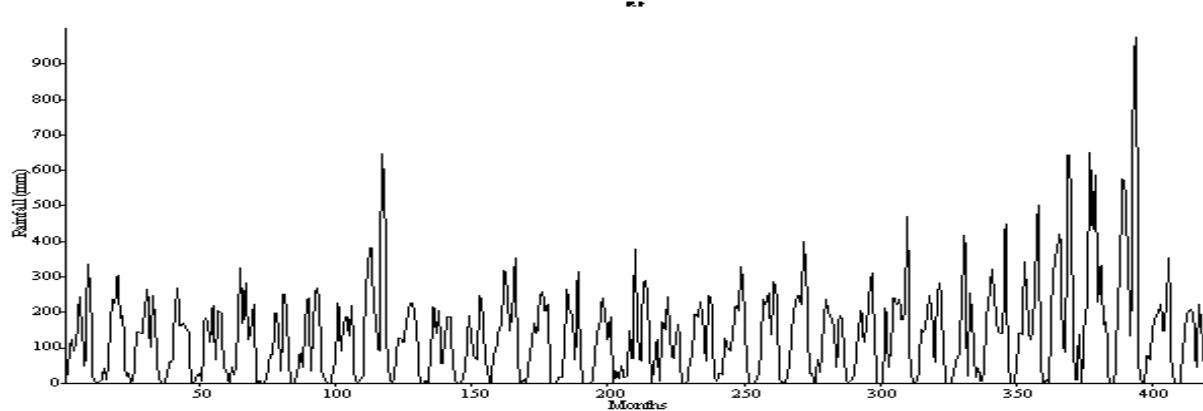
The data sets were subjected to descriptive statistics as well as analysis of variance irrespective of the year of planting. Means of the different treatment were separated using Duncan Multiple Range Test (DMTR). General linear model (glm) was adopted to describe the relationship between 2 variables (sources of variation and crop growth and yield) and to determine whether such relationship is statistically significant.

RESULTS

Rainfall Characteristics of Akure and Ibadan

The time series plot of the Ibadan rainfall showed that rainfall pattern for the site was irregular over the period of thirty-five years (Figure 1). It was shown that rainfall usually peak around June, September and with the least (0) was usually obtained around December, January and February. The irregular pattern however shifted up between February 2018 and October 2020. Similar irregular pattern was obtained for Akure rainfall data (Figure 1B) with a thinner range than Ibadan rainfall.

A



B

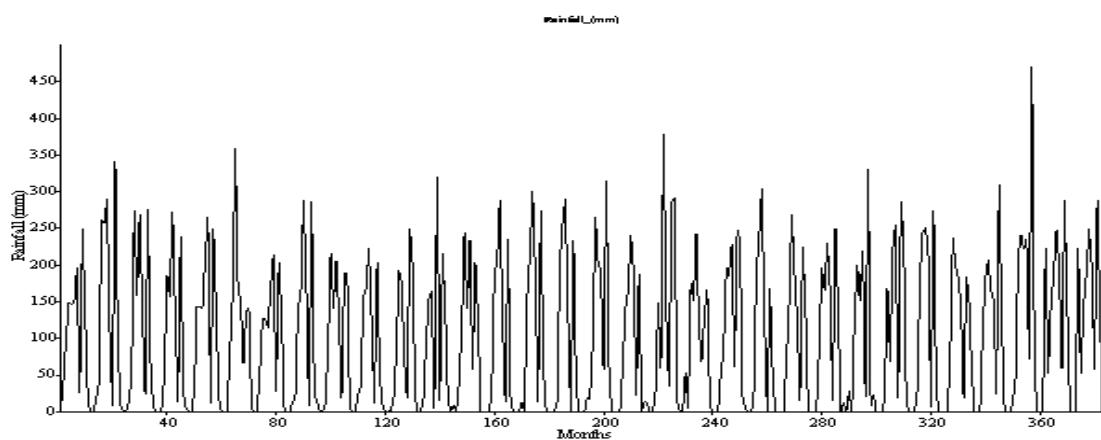


Figure 1: Time Plots of the Rainfall for the Ibadan (A) & Akure (B)

Total rainfall obtained for Akure in 2021 ranged between 438mm for planting date 3 to 679.5mm for planting date 1 with corresponding variance of 178.973 – 386.188 (Table 1). The mean and the variance of 2021 rainfall for Akure agree with each other. Mean 2022 rainfall for Akure falls between 500.7mm for planting date 1 and 585.6mm for planting date 2 while the variance ranged from 235.015 for planting date 3 to 284.607 for planting date 1. Mean 2021 rainfall for Ibadan followed a regularly increasing trend from 304.5mm for planting date 1 to 365.5mm for planting date 3 with variance of 139.211 for planting date 1 to 153.655 for planting date 3 (Table 1). Mean 2022 rainfall pattern inverse that of 2021 and it falls between 188.5mm for planting date 3 and 288.9mm for planting date 1. The variance decreases with increasing planting date from 122.328 for planting date 1 to 67.248 for planting date 3.

Table 1: Short Term Weather of the Study Areas

Years	Sites	Planting Date(PD)	Mean Periodic Rainfall	Variance
2021	Akure	PD1	679.5	386.188
		PD2	484.2	209.7411
		PD3	438	178.9732
	2022	PD1	500.7	284.6066
		PD2	585.6	275.3041
		PD3	546.6	235.0148
2021	Ibadan	PD1	304.5	139.2114
		PD2	330	147.2108
		PD3	365.5	153.655
	2022	PD1	288.9	122.3284
		PD2	211.3	79.51664
		PD3	188.5	67.24823

PD - Planting date

The descriptive analysis results showed that mean plant height, leaf area and number of leaves for Akure were higher than those of Ibadan. Plant height and number of leaves obtained for 2022 were higher than those of 2021. The leaf area returned for 2021 was however greater than the leaf area obtained for 2022. The variance of these variables followed the same pattern of the mean. Mean plant height (31.421) and leaf area (256.39) for variety 3 were the highest. Mean number of leaves returned for variety 1 (27.206) was the highest while mean number of leaves was the highest while mean number of leaves obtained for variety 2 (26.46) was the least (Table 2).

Table 2: Effects of Season, Variety, Planting Date and Location on Soybean Growth Variables

		Plant height (cm)		Leaf Area (cm ²)		No of leaves	
		Mean±SE	Variance	Mean±SE	Variance	Mean±SE	Variance
Sites	Akure	30.886 ± 0.941	334.929	286.762±14.661	81253.79	28.552± 1.128	480.9
	Ibadan	28.587 ±1.007	383.267	197.577± 4.79	8671.17	25.095 ±1.031	401.72
Years	2021	29.569± 0.973	357.741	251.18 ±14.452	78952.07	26.603±1.075	437.152
	2022	29.905± 0.98	363.046	233.159± 6.257	14796.64	27.05± 1.093	451.379
Varieties	V1	28.964±1.155	336.32	232.31±17.596	14359.55	27.206±1.358	464.555
	V2	28.825±1.149	332.543	237.81±17.596	78025.13	26.460±1.292	420.544
	V3	31.421±1.275	409.559	256.39±13.852	48351.49	26.814± 1.335	449.3396

The results of the summary statistics analysis alluded that mean number of pods per peduncle ranged between 17.833 for V3 and 20.722 for V2 and the variance falls between 0.892 for V1 and 3.349 for V2 (Table 3). Number of pods per plants followed similar pattern as the number of pod per peduncle with the range of 2.75 (V3) to 3.722 (V2). The summary of statistical analysis results obtained for pod length ranged from 6.333cm(for V2) to 16.056cm (for V3) and the variance falls between 1.029 (V2) and 1.942 (V1). Variety 2 has the least mean number of seeds per pod with 5.278seeds while variety 3 has the highest number of seeds per pod (8.083) and the variability falls between 0.663 - 8.204 for variety 2 – variety 3. The descriptive statistics analysis results of the number of pods per peduncle indicates that planting date 1 returned the highest number of pods pod per peduncle of 20.444 while the planting date 3 returned the least (18.444) number of pods per peduncle (Table 3). The variability of the number of pods pod per peduncle falls between 0.968 for planting date 2 and 4.311 for planting date 1 (Table 3). Planting date 3 produced the least peduncle per plants of 2.833 while planting date 1 produced highest t(3.694) peduncle per plants and the range was 0.390 – 0.657 (planting date 1 – planting date 3). The results of the analysis of the pod length indicated that the soybean's pod length fall between 10.167cm and 111.389cm for Planting date 3 and planting date 1respectively (Table 3). The pod length's variance is very high and range from 14.987



(planting date 1) to 19.914 (planting date 3). Number of seeds per pod was found to be between 5.833 (planting date 3) and 7.344 (planting date 1) with the variance of 2.968 and 7.949 for planting date 3 and planting date 1 respectively. Planting date 3 produced the least 100 seed weight of 12.306g while planting date 1 produced the highest 100 seed weight of 15.556g (Table 3). Akure has higher of number of pods per peduncle (19.370), higher peduncle per plant (3.426), higher pod length (10.778cm) and higher 100 seed weight (15.185) than Ibadan. The highest of the number of seed per pod (7.852) and yield per hectare which is 1671.99tonnes³ were however obtained for Ibadan. Highest number of number of pods per peduncle (19.296), highest 100 seed weight (14.575) and highest yield per hectare (kg) which is 23451.67tonnes³ were returned for 2022 while the least of those variables were obtained for 2021 (Table 3).

The $F_{(2, 604; 0.05)}$, 11032.3 and 99.33 (plant height); 8847.89 and 4.39 (number of leaves), 80.59 and 1.39 (leaf area) of both planting were all significant at $P < 0.05$ (Table 4). Similarly, the glm analysis for both sites and years returned $F_{(1, 604; 0.05)}$, 184.74 and 3.95 (plant height); 283.72 and 4.73 (number of leaves) as well as 52.09 and 2.13 (Leaf area) were all significant ($P < 0.05$). The $F_{(6, 604; 0.05)}$, 1891.39, 1668.43 and 21.33 obtained for plant height, number of leaves and leaf area were significant at $P < 0.05$. All the two variables interactions were significantly different from one another. The $F_{(2, 604; 0.05)}$, 1838.35 (plant height), 766.81 (number of leaves), 0.5532 (Leave areas) obtained for variety by Planting date; 1491.97 (plant height), 1245.14 (number of leaves), 6.59 (leaf areas) obtained for year by planting dates; 43.07 (plant height), 2.01 (number of leave) and 1.82 (leaf areas) obtained for sites by variety; 2.068 (plant height), 0.85 (number of leave) and 0.84 (leave areas) obtained for years by varieties were all significant at $P < 0.01$. Similarly, $F_{(4, 604; 0.05)}$, 6.92 (plant height), 3.97 (number of leaves) and 0.66 (leave areas) obtained for variety by planting date were significant ($P < 0.05$). Weeks after planting by planting date as well as weeks after planting by variety returned results that are significantly different for plant height ($F_{(12, 604; 0.05)}$, 107.16 – wap*PD; $F_{(12, 604; 0.05, 5.5 – wap*var)}$ number of leave ($F_{(12, 604; 0.05)}$, 143.64 – wap*PD; $F_{(12, 604; 0.05, 4.76 – wap*var)}$ and leave areas ($F_{(12, 604; 0.05)}$ = 2.25 – wap*PD; $F_{(12, 604; 0.05)}$ = 1.18 – wap*var) for both weeks after planting by planting date and weeks after planting by varieties.



Table 3: Effects of Season, Variety, Planting Date and Location on Yield and Yield Components of Soybean

Mean SE	NP PP		Pods PP		Pod L		NS PP		100 sdwt (g)		Yld (kg ha ⁻¹)	
	Mean±SE	Variance	Mean SE	Variance	Mean SE	Variance	Mean SE	Variance	Mean SE	Variance	Mean SE	Variance
V1	19.278±0.157	0.89206	3.167 0.129	0.6 0.232	9.667 1.94286	1.94286 0.341	6.1 4.189	4.189 13.444	0.597 0.129	1716.31 21.275	16294.78	
V2	20.722±0.305	3.349	3.722 0.13	0.606 0.169	6.333 1.029	1.029 0.136	5.278 0.663	0.663 13.389	281.902 1649.55	1649.55 22.287	17881.32	
V3	17.833±0.197	1.4	2.75 0.092	0.307 0.207	16.056 1.54	1.54 0.477	8.083 8.204	8.204 14.5	1.34 0.193	1623.38 27.121	26479.87	
PD1	20.444±0.346	4.311	3.694 0.104	0.39 0.645	11.389 14.987	14.987 7.344	7.344 7.949	7.949 13.472	1.971 1.971	1821.34 9.693	3382.27	
PD2	18.944	0.164	0.968	3.111 0.125	0.559 0.726	10.5 19	6.283 5.18	5.18 15.556	271.911 1663.67	1663.67 10.123	3689.32	
PD3	18.444	0.26	2.425	2.833 0.135	0.657 0.744	10.167 19.914	5.833 2.968	2.968 12.306	5.19 5.19	1504.23 13.53	6590.29	
Akure	19.370	0.262	3.709	3.426 0.108	0.626 0.615	10.778 20.403	5.122 0.122	0.806 15.185	179.701 179.701	1654.16 21.128	24104.71	
Ibadan	19.185	0.229	2.833	3.0 0.106	0.604 0.54	10.593 15.718	7.852 6.846	6.846 12.371	4.237 4.237	1671.99 18.713	18908.6	
2021	19.259	0.241	3.139	3.222 0.114	0.704 0.578	10.685 18.069	6.487 5.724	5.724 12.981	4.698 4.698	1665.38 19.106	19712.76	
2022	19.296	0.252	3.42	3.204 0.107	0.618 0.578	10.685 18.0688	6.487 5.72	5.72 14.575	181.985 181.985	1660.78 20.84	23451.67	

Table 4: General Linear Model (glm) Analysis of the Growth Parameters of Soybean.

SV	Df	F - Statistics (Soybean)		
		Plant height	No of leaves	Leave areas
Planting Date	2	11032.3*	8847.89*	80.59*
Sites	1	184.74*	283.72*	52.09*
Varieties	2	99.33*	4.39*	1.39*
WAP	6	1898.39*	1668.43*	21.33**
Years	1	3.95*	4.73*	2.13**
Sites*PD	2	1838.35*	766.81*	0.5532*
Var*PD	4	6.92*	3.97*	0.66**
WAP*PD	12	107.16*	143.64*	2.25*
Years*PD	2	1491.97*	1245.14*	6.59*
Sites*Var	2	43.07*	2.01**	1.82*
Sites*WAP	6	168.15*	237.69*	9.04*
Sites*Years	1	3.95*	4.73*	2.13**
WAP*Var	12	5.5*	4.76*	1.18**
Years*Var	2	2.68**	0.85**	0.84**
Years*WAP	6	235.8*	239.17*	6.25*
Sites*Var*PD	4	21.15*	1.00**	0.39**
Sites*WAP*PD	12	31.56*	19.79*	1.07**
Sites*Years*PD	2	1491.97*	1245.14*	6.59*
WAP*Var*PD	24	4.24*	7.65*	0.55**
Years*Var*PD	4	0.2338	0.45**	0.46**
Years*WAP*PD	12	18.69*	20.52*	0.99**
Sites*WAP*Var	12	3.31*	2.69*	1.12**
Sites*Years*Var	2	2.68**	0.85*	0.84**
Sites*Years*WAP	6	235.8*	239.17*	6.25*
Years*WAP*Var	12	1.31**	0.43**	1.01**

The glm analysis of the yield of soybean indicated that there exist significant difference in the mean number of pods per peduncle obtained for planting date and variety. The $F_{(2, 76;0.05)}$, 54.07 (planting date) and 104.14 (variety) were significant at $P < 0.05$ (Table 5). Similarly, the mean number of pods per peduncle returned for site by planting date, variety by planting date and site by variety were significant. The $F_{(2, 76;0.05)}$, 7.75 (site by planting date) and 10.06 (site by variety) as well as The $F_{(4, 76;0.05)}$, 12.4 (variety by planting date) were significant. None of the other main (sites and years) and interaction effects was significant ($P > 0.05$). Mean pods per peduncles obtained for planting date, site, variety and site by planting date were statistically significant. Mean pods per peduncle obtained for years and other interaction effects were not significant (Table 5). Mean number of seed per pod attained by different planting dates, sites and variety as well as site by planting date, variety by planting date and site by variety were significantly different ($P < 0.05$) (Table 5). Mean soybean yield (kg ha^{-1}) for planting date, sites, variety, site by planting date, variety by planting date, years by planting date, site by variety and site by years were statistically significant.

Table 5: General Linear Model (glm) Analysis of the Yield Parameters of Soybean.

Sources of Variation	Df	F statistics					
		NPPP	PodsPP	PodL	NSPP	100Seedwt	YldkgHa
Pdate	2	54.07**	23.86**	14.89**	43.24**	1.06	874.42**
Sites	1	1.28	16.81**	0.96	401.36**	2.32	8.29**
Variety	2	104.14**	29.39**	910.66**	149.4**	0.15	79.87**
Years	1	0.05	0.03	0	0	0.74	0.55
Sites*Pdate	2	7.75**	8.23**	6.6**	12.16**	1.24	7.45**
Var*Pdate	4	12.4**	1.56	7.29**	12.4**	0.88	7.91**
Years*Pdate	2	0.05	0.22	0	0	1.03	6.04**
Site*Var	2	10.06**	0.03	5.11**	134.73**	1.29	3.81*
Site*Years	1	0.05	0.03	0	0	0.74	121.83**
Years*Var	2	0.05	0.22	0	0	1.22	0.98
Site*Var*Pdate	4	0.59	1.18	1.07	1.12	1.01	1.88
site*years*Pdate	2	0.05	0.22	0	0	1.03	0.83
Years*var*Pdate	4	0.05	0.13	0	0	1.01	2.76*
Site*Years*Var,	2	0.05	0.22	0	0	1.22	3.57*

DISCUSSION

Generally, the growth and yield characteristics of soybean were found to be significantly influenced by planting date irrespective of the variety of soybean, location and year of planting. This is in agreement with Kim *et al* (2014) who discovered that the effect of planting date on growth and yield of soybean depends on the occurring time of the climate variables. Gibson and Javaid *et al* (2015) also found out that reduction in soybean were primarily the effects of variations in rainfall distribution pattern. Hassan (2018) also asserted that climate variability has negative effects on soybean production semi-arid regions. The results obtained from this study are in line with most previous studies indicating that as planting date is delayed, the growth characteristics of soybean are reduced. Examples are Boquet, (2020), Chaudry (2014), Cha and Chol (2015) and Hall (2018) who discovered that growth characteristics of soybean decreased with delayed planting. A positive correlation has been shown to exist between the growth and yield of soybean. This is corroborated by Ismail (2016) who found out that there exist correlations between plant height and pod-filling stages of soybean. Late planting had significant negative impacts on the vegetative growth and grain filling stages of soybean Salami (2010). There is a general decrease in the yield characteristics of soybean as planting dates was delayed. Salami (2010) also found out that decreased harvest index associated with late planting date of soybean. The effect of planting date on yield on yield characteristics of soybean is significant irrespective of the variety, location and year of planting. The finding is supported by the work of Sanginga *et al* (2013) who found out that earlier planting increases soybean yield. The findings was also supported by other studies which asserted that early planting may result in increased the soybean yield, but also dependent on climate variables such as rainfall [Rizzardi *et al* (2014); Rosenzweig *et al* (2014); Otequi (2015); Ray *et al* (2018)].

CONCLUSION AND RECOMMENDATION

Optimizing planting date of crop has proven to be a farm level adaptation strategy to the impacts of climate change and variability. The results from the two year field experiment in two locations within Rain-Forest Agroecology of Nigeria showed that the growth and yield of Soybean decreased with delayed planting. For optimum production of soybean in Rain-Forest Agroecology of Nigeria, soybean farmers are advised to plant at the onset of rain in the region.

REFERENCES

Ahmed, N.S. and C. Hartel (2019: Climate volatility deepens poverty vulnerability in countries. *Policy Research Working World Bank*, Washington DC. p.5117.



Ayoade, J. O. (2004): Introduction to Climatology for the Tropics. Spectrum Book Limited, Ibadan. Pp 146-168.

Boquet, D. J. (2020): Plant population density and row spacing effects on soybean at post-optimal planting dates. *Agron. J.* **92**: 59-64.

Cha, T. H. and H.O. Chol. (2015): The influence of the ripening character and 1000 grain mass change of maize hybrids at mountain areas on the yield. *Acad. Agric. Sci. Korea*, **1**: 32-35.

Chaudry, A.R. (2014): Cereal crop in crop productivity. *J. Plant Sci.* **32**: 272-285.

Hall AE (2002): Breeding for heat tolerance. John Wiley and Sons, New York, USA.

Hassan, K.H. (2018) Response of some maize cultivars to early planting dates under saline condition at siwaoasis. *Ann. Agric. Sci. Cairo*, **43**: 391-401.

Ismail, A. A. (2016): Gene action and combining ability for flowering and yield in maize under two different sowing dates. *Assiut J. Agric. Sci.*, **47**: 41-55.

IPCC, 2007: *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

Javaid J, Dadson RB, Hashem FM, Arthur LA (2015). Effects of insecticide spray applications, sowing dates and cultivar resistance on insect pests of cowpea in the Delmarva Region of the United States. *J. Sustain. Agric.* **26**: 57-68.

Kim, J., D. E. Waliser, C. A. Mattmann, C. E. Goodale, A. F. Hart, P. A. Zimdars, Mabhaudh, B. (2012): Drought-tolerance and water-use of selected South African Landraces of Taro (*colocassia esculata L Schott*) and babara groundnut (*Vigna subterrana*). PhD Thesis, University of Kwazulu-Natal, South Africa.

Otequi, M. (2015): Prolificacy and grain yield components in modern Argentinian maize hybrids. *Maydica*. **55**: 271-306.

Ray CL, Shipe ER, Bridges WC (2018). Planting date influence on soyabean agronomic traits and seed composition in modified fatty acid breeding lines. *Crop Sci.* **48**: 181-188.

Rizzardi, M.A., D. Witech and I. Deggerone, (2014): Grain yield and yield components of maize cultivars at two sowing dates. *Ciencia Rural*, **38**: 217-232.

Rosenzweig, C., Elliott, J., Deryng, D., Ruane, A. C., Muller, C., Arneth, A., et al. (2014). Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. *Proceedings of the National Academy of Sciences of the United States of America*, **111**(9): 3268-3273.

Salami, A. (2010): Climate change mitigation and adaptation options: The Nigeria experience. (UNEP, 2013): Climate change-home.

Sangina N, Dashiell KE, Diels J, Vanlauwe B, Lyasse O, Carsky RJ, Tarawali S, Asafo-Adjei B, Menkir A, Schulz S, Singh BB, Chikoye D, Keatinge D, Ortiz R (2013) Sustainable resource management coupled to resilient germplasm to provide new intensive cereal grainlegume-livestock systems in the dry savanna. *Agric. Ecosyst. Environ.* **100**: 305-314.

Shegrop, A., A. Atilaw and N. Geleta, N. (2020): Influence of variety and planting dates on growth and development of cowpea in Metekel zone, Northwestern Ethiopia. *Journal of Agronomy*, **9**(3): 148-156.