Speargrass [*Imperata cylindrica* (L.) Raeuschel] growth in relation to rainfall and temperature patterns of southern agro-ecologies of Nigeria.

Abstract

Speargrass pose a major constraint as weed pest in some agarian communities in Nigeria. Its endemic status significantly reduced yield in crops. Hence the study was conducted to investigate the influence of rainfall and temperature as growth factors on speargrass growth and invasiveness with the view to improve its management. Study was conducted between July 2014 and June 2016 in Eruwa (7˚32'0˚N, 3˚ 25'0 ˚E, 187m altitude) in derived savanna and Kishi (08˚.98'N, 003˚.94'E; 364m altitude) in the southern Guinea savanna–northern fringe agroecologies of Nigeria, showed the influence of monthly ambient temperature and rainfall patterns on speargrass dry matter accumulation. Twelve months of the year starting from July were randomly assigned to abandoned speargrass infested plots, replicated three time and arranged in Randomized Complete Block Design (RCBD) over the period (24 months). Monthly samples of speargrass shoot and rhizome biomass were collected from 1x1m quadrant/plot. The speargrass shoot was cut at soil level, while the soil was dug to 30 cm depth to collect rhizomes and weighed.

Result showed that total speargrass total dry weight (STDW) increased with rise in rainfall in both locations. Evidently, soil moisture is of essence in speargrass dry matter accumulation. Though, the amount of rainfall varied widely across the months in both locations. The highest rainfall was recorded in September (264.20 mm) and hotest month was may, 2016 (28.5^{o}C) at Eruwa between 2014 and 2016 (Table 1). Kishi had 186 mm rainfall in the wettest months and the hottest months had 28.0 ^{o}C within the specified period of the study (Table 2). There was decline in speargrass dry matter during the dry months (January to April) in the locations. This might have reflected the effects of soil moisture deficit as growth retardation, high transpiration and plant physiological tune to overseasoning and partial dormancy. Average ambient temperature across the months were comparable at both locations. Hence, speargrass total dry weight (STDW) was not influenced by temperature. Rainfall and temperature relationships with speargrass dynamics in Kishi (SGS) was similar to patterns in Eruwa (DS) as reported earlier. However, Kishi had reduced rainy months (May – August) *and therefore more dry months (September – April) than Eruwa. Hence, prolonged moisture stress in Kishi refelected lower speargrass total dry weight than Eruwa. Hence, speargrass dry matter accumulation was influenced by the rainfall patterns across agro-ecologies under the study..*

Keywords: speargrass, rainfall, temperature, agro-ecologies, dry weight

Introduction

Weed growth like crop plants, is influenced by atmospheric temperature and rainfall patterns of different locations. The influence of these growth factors determine to a large extend the types of crop grown and weed incursion or problems that farmers will management. Speargrass is a difficult-to-control weed (Holm *et al*. 1977). It invades 9 – 97% of farmers' field in West Africa and recurs as a major pest in cultivated areas of the upland and moist savanna and humid rain-forest agroecozones in Nigeria (Smith, 1997; Chikoye *et al*., 1999).

It marked infestation is evident in 73 countries and has been a major limiting factor in the cultivation of 35 annual and perennial crops (Brook, 1989). This accounts for between 62 and 90% yield reduction in maize, and 28.5% and 52.6% in soybean in the middle belt and southwestern Nigeria (Koch *et al*., 1990; Udensi, 1999; Avav, 2000; Aluko *et al*., 2012). Generally, speargrass management usually increases the cost of crop production and reduces the revenue generated from crop harvest. This cost will increase or decrease as weed species distribution changes in response to future changes in the climate (Hilbert *et al.* 2007).

Models of global climate predict that mean surface air temperature of the earth will rise by 1.5 - 4.5 ^{0}C in the 21st century, due to the doubling of CO_2 concentrations and the enhanced greenhouse effect (IPCC, 2001). Extreme high-temperature events are anticipated to increase in frequency. Plants, in many parts of the world, are thus likely to experience increasing high-temperature stress. However, the effect of increased temperature would be felt in different regions of the world differently. It could be argued that in sub-tropical and tropical regions, an increase of temperature by a few degrees could lead to an increase in EvapoTranspiration (ET) rates to a point that the growth of some species would suffer, due to moisture deficiency. However, changes in rainfall patterns would offset such species responses, under a changing climate. Temperature is the dominant factor that controls plant growth at high (above 50^0N) and mid latitudes (above 45^0N). At high altitudes, this is due to the influence of temperature on the length of the growing season. Probably the most significant effect of a future increase in temperature in regions where temperate is the main limiting factor, would be to extend the growing season available for plants. However, the effects of such warming on the length of the growing period will again vary from region to region and from crop to crop.

It is generally accepted that higher atmospheric CO_2 is likely to stimulate the growth of crops, and C_3 plants are the most likely to benefit. The consensus of three decades of research is that a doubling of CO_2 concentrations may cause a 10-50% yield increase in C_3 crops like rice, wheat and soybean (Kimball, 1983, Poorter, 1993), the corresponding yield increase expected in C_4 crops, such as maize, sorghum and sugar cane, is 0-10%. However, much will depend on prevailing growing conditions and adequate supply of water and nutrients. On the other hand, this may influence the endemic status of C_3 weed such as speargrass (*Imperata cylindrica* L.) and consequently crop yield reduction and profitable crop production may be adversely affected. The survival of both crops and weeds depend on the response to climate change. Nevertheless, the overall winners of their competition will be the colonising species, because of their superior adaptations and wide ecological amplitudes (i.e. the limits of environmental conditions within which an organism can live and function).

Although it is not possible to be specific, under climate change, weed management will become more important in the future at every scale, from farmlands to regional landscapes. As colonising species become abundant, and possibly more aggressive in many regions, humans will have to adapt to manage weed populations more effectively, in order to maintain productive landscapes and achieve food security. Control of weeds, pests and diseases are all likely to be more difficult and more expensive under climate change. Hence, the study investigated the effects of rainfall and temperature on speargrass dynamics in south-west Nigeria agro-ecologies to guide the decision in weed management intervention in speargrass endemic agroecologies.

Methodology

Experimental site

The land was an abandoned speargrass infested field at two agroecozones (Derived savanna - Eruwa, 7˚32'0˚N, 3˚ 25'0 ˚E, 187m altitude and Kishi 08˚.98'N, 003˚.94'E; 364m altitude southern Guinea savanna) between 2014 and 2016. The experimental land was a sandy loam soil, densely covered with speargrass.

An area of 71 x 17 m was marked out at each location for the study. The site was divided into twelve experimental plots measuring 5 x 5m with 1m alleyway. Twelve months of the year starting from July was randomly assigned to plots and replicated three time and arranged in Randomized Complete Block Design (RCBD). Monthly samples of speargrass shoot and rhizome biomass were collected from 1 sq.m quadrant per plot. The speargrass shoot was cut at soil level, while the soil was dug to 30 cm depth to collect speargrass rhizomes. The samples were oven-dry at 80 ˚C for 48 hours to determine the dry weight of both rhizome and shoot. Monthly means of amount rainfall and temperature data were obtained for the period which the samples were collected from Nigeria Meteorology station (NIMET) Ibadan. Data were subjected to analysis of variance (ANOVA), using Statistical Analysis System (SAS) and means were seperated with Duncan's Multiple Range Test (DMRT) at 5% level of probability (P = 0.05). Survey of speargrass density was also conducted in 2016 to validate the growth pattern of speargrass as influenced by Temperature and rainfall pattern across the agro-ecologies. 264.20 Figure 1 shows the marked portions of the map representing the study areas. Irepo LGA is located in the Southern Guinea savanna – northern fringe and Ibarapa East LGA is situated in the Derived savanna agro-ecologies of Oyo State.

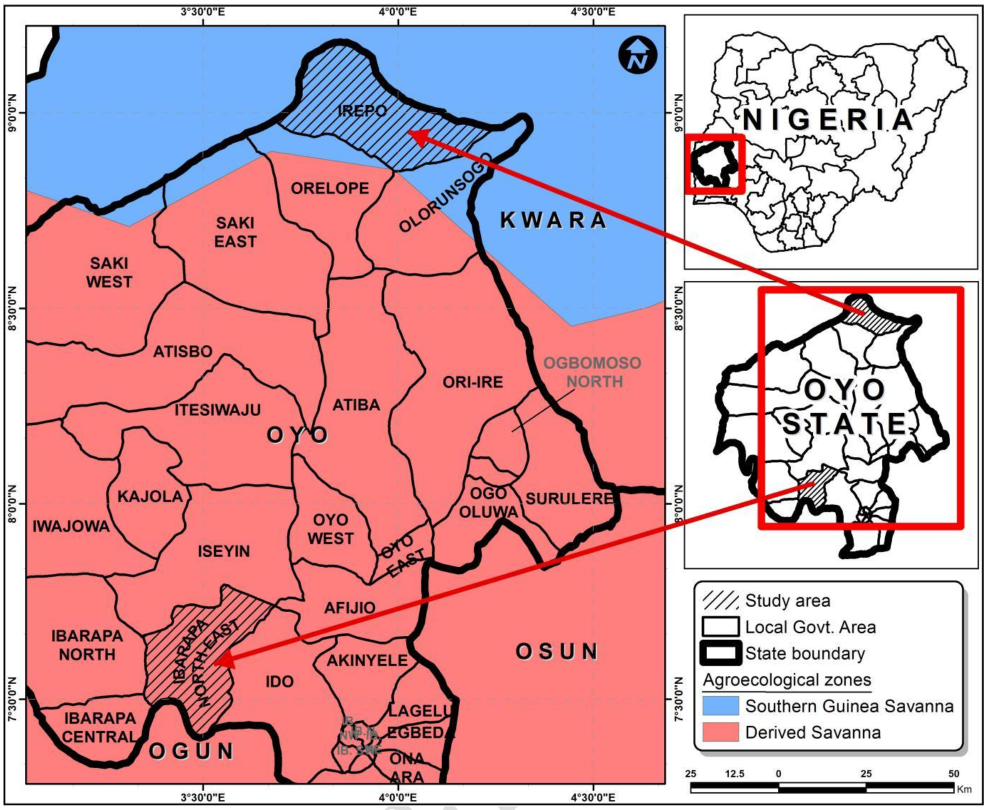

Figure 1: Map showing the study areas in shaded portions (Aluko *et al*. 2018)

Results

Effects of temperature and rainfall on speargrass growth in Derived savanna and southern Guinea savanna.

Table 1 shows the relationships between rainfall, temperature and speargrass dry matter accumulation at Eruwa (Derived savanna-DS agro-ecology) between 2014 and 2016. The amount of rainfall varied widely between seasons and years. The highest rainfall was recorded in September (264.20 mm), with the lowest in November, 2014 to February, 2015. Similar rainfall pattern was recorded in November, 2015 – February, 2016 in Eruwa (DS). Though average ambient temperature readings across the months was highest in February and June, 2016 (28.5 ^{o}C). This was comparable with other months within the study period of two

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three?? years except september, 2014 and 2015 (25.5 ^{o}C), and December, 2015 (24.5^{o}C) that were comparable at Eruwa (DS).

Table 1: Effects of Rainfall and Teperature on speargrass dry matter in Derived savanna agroecology (Eruwa)

Year	Months (24)	Rainfall (mm)	Temperature (^{o}C)	Shoot dry weight (g)	Rhizome dry weight (g)	Total dry weight (g)
2014	July	168.8c	26.5ab	116.30ef	135.75c	252.05
2014	August	124.4de	26.0ab	201.10cd	113.13cd	314.23d
2014	September	264.2a	25.5b	262.40c	128.92cd	391.32cd
2014	October	204.3b	26.5ab	329.10b	107.04cd	436.14c
2014	November	26.3g	26.5ab	107.10e	81.93de	189.03g
2014	December	0g	27.5a	229.50c	134.73cd	364.23d
2015	January	2g	27.0a	204.10cd	158.08c	362.18d
2015	February	16g	27.5a	213.20cd	215.79ab	428.99c
2015	March	57f	28.0a	186.00d	102.47cd	288.47de
2015	April	139d	27.5a	112.50de	87.96de	200.46fg
2015	May	156c	27.5a	117.80de	95.17cd	212.97f
2015	June	182b	26.0ab	180.03cd	72.80de	252.83ef
2015	July	173bc	26.0ab	136.30de	175.75bc	312.10d
2015	August	115de	26.0ab	206.10cd	123.13cd	329.30d
2015	September	192b	25.5b	362.40b	158.92c	521.3b
2015	October	29.0fg	26.5ab	539.10a	167.04bc	706.1a
2015	November	5.0g	26.5ab	87.10ef	58.93e	146.1g
2015	December	2.0g	24.5b	219.50cd	154.73bc	374.3cd
2016	January	0g	27.0a	238.90c	148.08cd	387cd
2016	February	8g	28.5a	253.20c	265.79a	519b
2016	March	48f	28.0a	236.00c	97.47de	333.50d
2016	April	107e	28.0a	62.50f	80.96de	143.40g
2016	May	149c	28.5a	124.80de	93.17de	217.90f
2016	June	178bc	27.0a	203.30cd	57.80e	261.10ef

Means with the same alphabet(s) are similar within the specified duration of the study (2014 to 2016) at p=0.05

Table 2 showed the ranfall and temperature patterns at Kishi (Southern Guinea savanna-SGS) within the specified study period. Rainy month of June 2015 had the highest amount of rainfall (192 mm). This was similar to amount of rainfall recorded in september (2014 & 2015), and June 2016 (184 mm). The highest temperature was 28.0^{o}C within the study period at Kishi (SGS). This was comparable with other months except August, 2014 (25.0^{o}C).

The pattern of speargrass total dry weight is consistent with the variations in speargrass rhizome and shoot dry weight. During the dry months (January to April), there was a decline in speargrass dry matter. Speargrass total dry weight increased gradually with increase in speargrass shoot dry weight as a component of the total dry weight. This followed the trend of rise in rainfall over the rainy months of May to October before a sharp decline from the crest as observed in the (Table 1). This was similar to the relationship of speargrass component yields to rainfall pattern and temperature recorded at Kishi (Table 2). However, Kishi had reduced rainy months (May – August) and more dry months (September – April) compared with Eruwa, and lower speargrass component yields and total dry weight were recorded in SGS (Table 2).

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Table 2: Effects of Temperature and rainfall amount on speargrass dry matter at southern Guinea savanna (Kishi)

Year	Months (24)	Rainfall (cm)	Temperature (°C)	Shoot Dry Weight (g)	Rhizome Dry Weight (g)	Total Dry Weight (g)
2014	July	166b	26ab	310.25a	103.27b	413.52ab
2014	August	144c	25b	60.66cd	143.74ab	204.40d
2014	September	186a	25.5a	49.86d	150.85ab	200.71d
2014	October	79e	26.5a	119.90bc	129.7ab	249.60cd
2014	November	9g	27.5a	79.54cd	97.69b	177.23de
2014	December	2g	28a	128.51bc	162.39ab	290.90c
2015	January	0g	27.5a	62.22cd	206.42a	268.64cd
2015	February	0g	27.5a	88.64cd	137.26ab	225.90cd
2015	March	5g	28a	89.92cd	86.56b	176.48de
2015	April	45f	26ab	123.18c	101.72b	224.90cd
2015	May	109d	27a	203.06b	139.17ab	342.23bc
2015	June	192a	25.5b	166.8bc	124.60ab	291.40c
2015	July	166b	26.5a	410.25a	73.27ab	483.50a
2015	August	142c	26.5a	70.67c	193.94ab	204.6de
2015	September	186a	26a	39.86d	135.86ab	175.70de
2015	October	82e	26.5a	129.92bc	109.7ab	239.6de
2015	November	2g	27.5a	99.54bc	70.79ab	170.30de
2015	December	1g	27.5a	98.61bc	64.39ab	163.00e
2016	January	0g	28a	73.72bc	226.42a	305.10bc
2016	February	0g	28a	73.64bc	147.28ab	220.90cd
2016	March	0g	28a	119.9bc	96.56ab	216.50cd
2016	April	34f	27.5a	113.18bc	91.75ab	204.90de
2016	May	121d	27a	213.06b	169.19ab	382.20bc
2016	June	186a	26.5a	160.8bc	34.64b	194.4de

Means with the same alphabet(s) are similar within the specified duration of the study (2014 to 2016) at p=0.05

Discussion

Differential responses of weeds to prevailing environmental factors like rainfall (intensity, distribution), temperature, cloudiness, relative humidity and edaphic characteristics influence weed competition and their survival in cropping situations (Das, 2011). Hence, temperature and rainfall patterns significantly influence weed-crop interaction, weed survival and invasiveness in agroecozones. The study showed significant variations in rainfall and temperature patterns in both Derived savanna (Eruwa) and sothern Guinea savanna (Kishi) both in oyo state of Nigeria. These are agrarian communities with arable/food crops as their farm produce and source farm income. However, the devastating effect of speargrass was earlier documented by Aluko et al. (2019) in most farmland and from reports obtained from farmers especially in Derived savanna (Eruwa) and southern Guinea savanna (Kishi) agroecologies in shaded portions in Figure 1.

Results in this study showed a significant increase in speargrass total dry weight (*STDW* - 413.52 g/m^{-2}) with an incease in rainfall in July 2014 and 2015 at 26.0^{o}C and 26.5^{o}C of temperature respectively. Speargrass had significantly high shoot growth (310.25 g/m^{-2}) in July, 2015. Evidently, speargrass significant physiological response to nutriets available for growth and biomass accumulation in 2014 and 2015 in southern Guinea savanna (Table 2).

In constract to this, in August 2015; reduction in speargras dry matter following reduced showers of rain and high temperature. Notwithstanding, speargrass biomass was sustained with significantly higher rhizome dry matter which was over two times of the shoot dry weight. The annual fluctuations in dry matter accumulation and rainfall resulted from dry spell and heavy showers might be implicated in speargrass growth, persistence and invasiveness. Speargrass invasiveness may be more pronounced where other competing weeds are adversely affected by the dry spell in August and the prolonged dry season in November to March with little or no rainfall (0 - 8mm). Altough, weeds noted around this agroecology (DS & SGS) are predominantly annual weeds which are naturally seeded into the seedbank unlike propagative rhizomes with better start. Rainfall intensity and distribution play significant role in speargrass dry matter accrual and invasiveness.

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The increase in speargrass dry matter during the rainy seasons and decline in total dry matter of speargrass during the dry months at both locations were a reflection of the effect of rainfall on speargrass growth and its invasiveness. Relatively, higher rainfall recorded in the Derived savanna (Eruwa) accounted for more speargrass total dry matter over southern Guinea savanna (Kishi). This is in line with the report of Aluko *et al*. (2018). It is therefore safe to conclude that relatively high soil moisture enhances speargrass dry matter and rhizome elongation in locations. The variation in speargrass dry matter is thus influenced by differing rainfall amount in the agro-ecologies, which might have significant effect on speargrass density and geographical range covered as earlier reported by Aluko (2018). This is also in resonance with Ibe (2010), that speargrass dry matter is affected by the location of infestation. The factors of rainfall and difference in location invariably influence the biodiversity of the locations investigated. The abundance supply or shortage of rainfall play significant role, this in turn influence ecological flora richness of the ecology. Where competing weed species are lacking or could not overseason successfully apart from the seasonal resurgence through seeding, perennial and noxious weeds tend to form a strong niche and establish invasive geographical range. Furthermore, according to Patterson, (1995), the invasiveness of weeds like Itchgrass (*Rottboellia cochinchinensis*) in the same grass family with speargrass may increase with 3 $^{\circ}$C rise in temperature. Where temperature is on the incresease, other species may succumb to hot weather and this may affect their fecundity and survival. In this study, a little rise in temperature in July 2014 favoured biomass accumulation.

A critical look at the speargrass growth pattern in relation to rhizome-shoot ratio might give an insight into its vulnerable growth phase for management intervention. In August 2014 and 2015, there was reduction in total dry matter accumulation. However, a shift in accumulated dry matter skewed to the rhizome. According to Ziska *et al*. (2004), an increase in the root-shoot ratio may play a critical role in herbicide efficacy. Thus, vigorous root growth at the expense of shoot may reduce herbicide efficacy due to poor translocation. Dense speargrass rhizome may provide a succour to the plant through its buffer effect from the food reserve in the underground portion. Notwithstanding, higher shoot-rhizome ratio in other months at both locations may provide large surface area for herbicide contact and translocation. Furthermore, uptake of herbicides is reduced with a rise in ambient temperature as weeds develop resistance that prevent translocation of herbicides (Bailey, 2004; Chandrasena, 2009; Rodenburg *et al*., 2011). This gives further insight into the spread and endemic status of speargrass in these agro-ecozones in relation to seasonal fluctuation of rainfall and temperature as key factors of growth and invasiveness of speargrass. The distribution of rainfall may be erratic and less predictable in the future; spread and prevalence of problematic weed such as speargrass may remain endemic as speculated by Peters and

Comment [MP5]: If possible, plot a graph to determine the correlation coefficients.

Comment [MP6]: Were the rhizome lenths measured. If not, the conclusion is not valid.

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Comment [MP8]: Data are available in the two tables. Add columns for shoot:rhizome ratios to make concrete references.

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Gerowitt (2014). This might also influence the crop-speargrass interaction as abrupt changes in climatic variables (rainfall and temperature) among others, may result in stressed crop plants which are vulnerable to insect pest and pathogens (Reddy, 2013), and less competitive against weeds (Patterson, 1995). These subtle changes in weather elements may call for future development and adjustments in crop production technologies, management practices and legislation as speculated by Bhat and Jan (2010). This will inform the method(s) and timing of weed management intervention to be adopted at different agro-ecologies to enhance season-long speargrass suppression and the management of other noxious weeds.

Conclusion

Rainfall patterns and distribuion are significant in the persistence and dry matter accumulation of speargrass as recorded in the study, apart from the cropping systems and weeding methods earlier reported to influence speargrass invasiveness in farmers' field. Identifying vulnerable speargrass growth phase for appropriate management intervention may provide a succour to resource poor farmers. Crop improvement and cultivation of crop genotypes with weed-suppressive traits can give a good return in speargrass infested farmland.

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