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Effect Of Locations And Population Density On The Growth And Biomass Yields Of Sweet Annie (Artemisia Annua) In Three Agro-Ecological Zones Of Nigeria

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Abstract:** Field trials were conducted at National Horticultural Research Institute (NIHORT) Dardin Kowa, substation Gombe state, Mbato substation Okigwe, Imo state and University teaching farm Uyo Akwa Ibom State in the late cropping season of 2016 and early cropping season of 2017 to evaluate location and population effects on growth and Biomass yield of sweet Annie. The soils of the study areas varied between: sandy to loamy; poor in organic to rich in organic matter and then the climate from less than six months of rains to throughout the year rounds of rainfall. Seedlings were after two months in the nursery transplanted on plots of 3m X 3m dimensions at varying spacing of 0.25m x0.25m; 0.5m x 0.5m; 0.75mx 0.75m; 1.0m x 1.0m; 1.25m x 1.25m; 1.50m x 1.50m; 1.75m x 1.75m; 2.0m x 2.0m that serves as the treatments. The trial was laid out in a randomized complete block design (RCBD) in three replications. A recommended basal dose of NPK, 100kg/ha was applied. All growth and Biomass yield data generated were subjected to analysis of variance (ANOVA) test. Also sampling of insect pest species was done weekly. The identified major insect pest of vegetables that includes leaf beetle (Podogrica spp); Cotton Stainer (Dysdercus spp); White flies (Bemissia tabacci); plant bug (Leptoglossus autralis); Leaf rollers (Sylepta derugota) and Grasshoppers(Zenocerus variegatus) were seen to only hover around the plants; in few cases perch for a and then fly away without any harm on the plant..That insect pest dares to perch late alone cause any harm suggest that Artemisia plant holds potential as a biopesticide. Closer plant spacing populations of 0.25m x 0.25m; 0.5m x 0.5m gave high cluster of interwoven canopy spread with strong indications of weed suppression and etiolating that decreased with increasing wider spacing and with resultant increased biomass yield in all the locations under observation. Growth parameters peaks ranged between 175cm – 236cm heights; 79.6cm - 177.4cm canopy spread diameters; 53 -92 number of petiole and 1.1cm – 2.4cm stem girths per plant across all the locations. Whole plant fresh biomass weights ranged 1.0kg – 1.53kg while whole plant dry biomass ranged 0.14kg – 0.4kg per plant respectively. Fresh leaf biomass ranged 0.22kg – 0.54kg per plant. Dry green leaf biomass per plant ranged 92.5 – 190.2g per plant translating into a ranged 442.5 – 20000 kg per ha. The highest Biomass yields were observed on 0.25m x0.25m lower spacing suggesting plant population advantage over higher spacing with low population. Also plant fresh inflorescence ranged 74g – .200g while 32.3g – 75.6g range of dry inflorescence per plant respectively were recorded across the location under review. The study started nursery activities across these locations in march; transplanting in May and June; flowering spread across months of August, September, and October thus suggesting a life cycle of about six months. This is a strong indication that sweet Annie is suggestively a day neutral plant hence flowered before the dry season sets in across all the locations. Also, the results here suggests that wider spacing of 1.0m x 1.0m to 1.75m x 1.75m and even 2.0m x 2.0m could be used perhaps for breeding purposes or other related trials for optimum yield per plant of Sweet Annie in any of these locations and also in line with their rainfall patterns.

***Keywords:** Artemisia, Biomass, inflorescence, locations, light sensitivity, spacing, and plant population.*

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I. INTRODUCTION

Artemisia annua, also known as sweet wormwood, sweet annua, sweet sagewort and annual wormwood (Chinese: inghao) is a common type of worm-wood that is an annual aromatic herb, native to China which occurs naturally in steppe vegetation in Northern China at a latitude of 40^0 and altitude from 1000 – 1500 m above sea level but naturalized throughout the world ((Ferreira *et. al.*2005; Wikipedia 2012). It belongs to the class, Magnoliopsida; Subclass, Asteridae; Order, Asterales; Family, Compositae; Genus, Artemisia; Specie, annua (Diemer and Griffee,2006). It is a determinate

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short-day plant with family having about 400 species(2n= 36) and characterized with extreme bitterness of all parts of the body and with three common anti-malaria chemical derivatives namely Artesunate, Artemeter and Artemisinin (Bennett *et.al*.1982; El-haq *et.al*.1991; Tripathi *et.al*.2000; Jaime and Da silver, 2003;Ferreira *et.al*.2005;Tahir *et.al*.2013;Tahir *et.al*.2016). . It has fern-like leaves, height averages about 2 meters; has single stem; alternating branches and leaves; cross pollinated by wind or insects (Kreitschitz, 2003). Artemisia does best in open, sunny positions or fertile sandy loam and alluvial soils that are neutral to slight acidic and retains moisture; thus does not tolerate draught or water logging. A basal fertilizer rate of 100kg NPK per Ha was recommended by Ferreira et.al. (2007) .In China and Vietnam its life cycle is ten months while in Europe and America six months (Kew 2008). Sweet wormwood is the source of the traditional Chinese medicine (TCM) Qing Hao which has been used for more than 2000 years to alleviate fevers (Kew, 2008) . The Chinese Pharmacopoeia lists the dry herb as a remedy for fever and malaria (Wikipedia 2015). Malaria is one of the six killer disease that were endemic in 106 countries of which 99 had on- going malaria transmission with 86% of its death role on children under five years of age(Williams et.al.2013; Abolaji et.al.2016). It is estimated that 1.5 million people die every year of malaria and on average of 30 seconds a child dies too(Rezelman and Goris,2008). Studies by Abolaji et.al.(2013)showed that after using the tea extracted from the dried leaves of the A-3 Artemisia; four individuals felt calm and relaxed, had sound night sleep,cleared nasal and head stuffiness and relieved from malaria symptoms on the third day of taking a liter of tea per day for 7 days.Artemesinin as an anti-malaria. Compounds produced by *Artemisia annua* has saved millions of live suffering malaria (Brisibe, 2006; Bina Bhattarai,2016). While Wikipedia(2015) highlighted daily dose description of 4.5 - 9.0 grams of dried herb as tea infusion REAP(2013) dosage recommendation pointed out capsules containing 500mg of powdered dry leaves of Artemisia or alternatively as pointed out by WHO (2006) daily dose is between 100 and 200 Mg of Artemisia semi-synthetic derivatives in artemisinin-based combination therapies-ACT. Some artemisinin-based therapy drugs in Nigeria includes Lonart-Ds, Lysunate, Lumartem, Coartem, and Amartem. Artemisinin therapies is extremely important in treating malaria especially in killing the most dreaded parasite; *Plasmodium falcipurum;* .the very specie of malaria parasite that is globally known to be resistant to many other anti-malaria(Kew, 2008).. Combating malaria has become one of the greatest wars of World Health Organization (WHO). Shariff (2010) placed the cost of one unsubsidized treatment of malaria using artemisinin- based drug at 1.5 US dollars. This is quite expensive for the malaria ravaged rural poor of developing countries. Shariff (2010) reported that Artemisia can be grown as cash crop that will enhance raw material for local production of ACT in Nigeria and demonstrated the domestication of *A. annua* in selected geopolitical zones of the country. The production and supply chain need to grow and significant public and private intervention are required to make an effective and affordable anti-malaria drug available to Nigeria populace (Abolaji et.al. 2016). It is the domestication of *A. annua* already started by Shariff (2010) that prompted this ,multi locationally evaluation the Artemisia plant in Dadin Kowa, Mbato and Abak of Nigeria..

II. MATERIALS AND METHODS

Field trials were conducted in three agro ecological zones namely National Horticultural Research Institute (NIHORT) Dadin Kowa station, Gombe State; Mbato station, Imo State and University Teaching Farm Abak, Akwa Ibom State in the late cropping season of 2016 and early cropping season of 2017 to evaluate location and population effects on the growth and biomass yield of sweet annie. Earlier years nursery raising of the seedlings failed to give good plant population until the nursery soils were steam sterilized.

Dadin Kowa, Mbato and Abak have geographical locus of $11^{0}14^{1}$N, 11^{0} 8^{1}E 440 meters above sea level; 05^{0} 37^{1}N, $07^{0}23^{1}$E, 130 meter above sea level and 03^{0} 28^{1}N, 08^{0} 2^{1}E, 80 meter above sea level respectively. Nursery activities using plastic trays as receptacles and rich top soils started across these locations in the month of March. Prepared fields were raised to beds of 4m x 4m in dimensions. Pre-planting soil samplings of the various plots were collected from 0-20cm depth using soil sampling auger. The soil of the study area varied between sandy to loamy; poor in organic to rich in organic matter with climates from less than six months of rains to throughout the year round of rainfall. Plant spacing of 0.25m x 0.25m; 0.5m x 0.5m; 0.75m x 0.75m; 1.0m x 1.0m; 1.25m x 1.25m, 1.5m x 1.5m; 1.75m x 1.75m and 2.0m x 2.0m totally eight serve as the treatments. The trial was laid out in a Randomized Complete Block Design with three replications. Seedlings at two months of age were transplanted to their respective plot in the month of May. A basal NPK rate of 150kg/ha was applied as recommended for sun flower; a member of sweet annie family was applied in split does at one month and three months after transplanting (MAT). All growth and biomass yield data generated were subjected to analysis of variance (ANOVA) test. Also sampling of major vegetables insect pest, species was done at weekly bases.

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III. RESULT AND DISCUSSION

The result of this study suggests that Artemisia can be domesticated in any of the three zones in Nigeria under review as earlier pointed out by Shariff (2010) who demonstrated it in six pilot states that did not include Okigwe Imo State and Abak Akwa Ibom State.

Properties	Gombe	Okigwe	Abak
PH (1.1H₂0)	5.2	4.99	4.92
Organic carbon (g kg^{-1})	5.0	4.9	5.4
Total nitrogen (g kg^{-1})	0.214	0.88	0.99
Available P (mg kg^{-1})	3.30	7.1	9.11
Exchangeable Ca (mol$_c$ kg^{-1})	1.82	3.01	4.21
Exchangeable Mg (mol$_c$ kg^{-1})	0.78	1.71	1.87
Exchangeable k (mol$_c$ kg^{-1})	0.13	0.169	0.11
Mechanical analysis			
% Sand	61	67	52
% Silt	19	16	31
% Clay	21	17	17

Table 1: Some Physical – chemical characteristics of Study Areas Soils

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Table 1 shows the soil physio- chemical properties of the multy locational trial sites of the study.

	A Month after Transplanting: Plant heights (cm)			2 Months of Transplanting: Plants Heights (cm)			3 Months after Transplanting: Plant Heights (cm)			4 Months after Transplanting: Plant height (cm)		
Spacing Densities	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak
0.25 x 0.25m = 160,00	18.5	20.1	19.2	40.8	45.6	49.5	178.3	1.90.1	*210.5	210.5	230.1	*229.8
0.5m x 0.5m = 40,000	17.1	18.1	16.1	38.6	41.5	42.9	170.5	180.4	200.6	201.6	215.6	236.1
0.75m x 0.75m = 17,777	18.2	16.4	20.5	42.6	49.6	52.1	161.7	175.6	190.8	196	221.2	225
1.0m x 1.0m = 10,000	14.9	15.4	18.6	53.3	44.7	39.6	146.9	165.2	179.0	199.5	205.1	210.5
1.25m x 1.25m = 6,400	16.7	19.6	18.6	35.6	41.6	50.1	129.5	146.8	155.1	189.5	196.5	215
1.5m x 1.5m = 4,4444	15.8	17.7	16.8	44.5	38.6	46.3	121.1	136.8	146.8	179.9	180.1	196.4
1.75m x 1.75m = 3262.5	18.0	19.1	15.9	46.7	48.9	52.0	118.2	128.9	138.7	184.3	190.6	199.5
20m x 2.0m = 2500	17.5	14.6	16.6	49.6	53	*55.0	128.6	122.4	131.3	174.6	185.0	200.1
LSD (0.05)		NS			18.1			91.1			49.6	

NS = Not Significant * = Significant ** Highly Significant

Table 2: Effect of Locations and Population Density on the plant Heights of Sweet Annie (Artemisia annua) in three Agro-ecological zones of Nigeria

Table 2 shows the plant height at one month, two month, three month and four month after transplanting, (MAT) across the locations. Plant heights increased by the months to reach peak at 4MAT. There was no significant (p≤0.05) difference in plant heights at one month after transplanting across the locations. But there were significant (P ≤ 0.05) difference at two, three and four months after transplanting (4 MAT) as the height agree with average of 2 meters reported by Kreistchitz (2003). The least heights of 174.6, 180.1 and 199.5cm were observed at 4 MAT in Dadin Kowa, Mbato and Abak. Maximum heights (199cm, 230cm and 229.8cm) at spacing 2m x 2m and 1.5m x 1.5m were recorded for Gombe, Okigwe and Abak locations respectively at 4MAT. *Artemisia annua* plants can grow as much as 1.8 – 2.2m tall in the green house and 1.2 – 1.8 m tall if potted (Bina et .al.2016).

	A Month after Transplanting: Canopy Spread Diameter (cm)			2 Months of Transplanting: Canopy Spread Diameter (cm)			3 Months after Transplanting: Canopy Spread Diameter (cm)			4 Months after Transplanting: Canopy Spread Diameter (cm)		
Spacing Densities	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak
0.25 x 0.25m = 160,00	9.2	12.6	13.5	21.7	28.7	31.5	77.7	86.2	93.1	79.6	91.1	96.5
0.5m x 0.5m = 40,000	10.8	13.6	14.6	20.1	26.1	25.1	75.6	81.2	94.6	81.5	95.1	99.9
0.75m x 0.75m = 17,777	8.8	11.2	10.6	24.4	31.6	30.1	79.2	85.1	91.8	82.1	99.6	105.6
1.0m x 1.0m = 10,000	11.1	10.1m	9.8	27.0	28.6	19.9	82.4	97.5	98.2	90.6	110.2	111.7
1.25m x 1.25m = 6,400	10.9	12.5	14.0	18.5	24.5	31.0	90.5	105.0	109.1	92.3	125.1	141.3
1.5m x 1.5m = 4,4444	9.8	10.6	11.6	27.1	19.2	28.3	92.6	105.0	112.6	121.4	151.6	167.1
1.75m x 1.75m = 3262.5	12.7	9.8	10.8	28.5	30.1	32.1	96.8	111.0	116.7	128.1	152.6	170.6
20m x 2.0m = 2500	8.6	12.1	11.4	33.0	35.0	34.0	98.8	*119.0	*121.6	130.2	*159.4	*177.4
LSD (0.05)		NS			NS			41.7			89.16	

NS = Not Significant * = Significant ** Highly Significant

Table 3: Effect of Locations and Population Density on the canopy spread diameters of Sweet Annie (Artemisia annua) in three Agro-ecological zones of Nigeria

Tables 3 shows the canopy spread diameter (cm) at one, two, three and four MAT across Dadin Kowa, Mbato and Abak. There were no significant (P ≤ 0.05) difference for canopy spread diameter (cm) at one and two MAT.; but there were as canopy spread diameter increased by the months like plant heights at 3 and 4 MAT with Abak and Okigwe recording highest canopy spread diameters of 177.4cm and 159.4cm respectively at 2m x 2m spacing.

	One month After Transplanting: No of petioles Per plant			2 Months After Transplanting: No of petioles Per plant			3 Month after Transplanting: No of petioles Per plant			4 Months a Transplanti No of petio Per Plant	
Spacing Density	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak	Gombe	Okigwe
0.25m x 0.25m = 160,00	18	21	20	39	44	38	50	54	62	53	59
0.5m x 0.5m = 40,000	17	19	18	41	41	37	52	56	68	56	61
0.75m x 0.75m = 17,777	20	22	17	43	46	48	55	58	65	60	65
1.0m x 1.0m = 10,000	19	21	19	50	48	52	60	64	70	68	71
1.25m x 1.25m = 6,400	21	19	22	48	50	41	61	59	72	72	75
1.50m x 1.50m = 4,444	19	20	21	51	39	44	64	65	*75	76	78
1.75m x 1.75m = 3265	20	18	19	42	40.1	46	65	66	*77	73	80
2.0m x 2.0m = 2500	18	19	22	39	41	43	61	67	70.0	79	86
LSD (0.05)		NS			NS		25.0				36.1

NS = Not Significant * = Significant ** Highly Significant

Table 4: Effect of Locations and Population Density on the number of Petioles of Sweet Annie (Artemisia annua) in three Agro-ecological zones of Nigeria

Tables 4 shows the number of petioles per plant at one, two three and four months after transplanting which increased by the months across Gombe, Okigwe and Abak to reach peak values at 4MAT. At one and two MAT there were no significant (P≤ 0.05) difference for number of petioles per plant but there were at 4MAT with Gombe, Okigwe and Abak giving at the widest spacing (2.0m x 2.0m) the highest petioles numbers; 79, 86 and 92 respectively. Tahir et.al.(2017) reported a maximum of 76 number of leaves an asexual propagation trial.

	One month after Transplanting: Lengths of petiole (cm)			2 Months after Transplanting: Lengths of petiole (cm)			3 Month after Transplanting: Lengths of petiole (cm)			4 Months after Transplanting: Lengths of petiole (cm)		
Spacing Density	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak
0.25m x 0.25m = 160,00	6.9	8.1	7.6	13.6	14.2	15.6	31.6	38.8	42.1	59.6	65.5	74.4
0.5m x 0.5m = 40,000	7.1	6.8	6.7	14.9	16.0	17.0	32.5	40.1	39.4	67.7	75.1	81.5
0.75m x 0.75m = 17,777	6.7	7.1	8.0	13.8	14.9	16.1	36.7	38.3	38.3	70.2	86.3	89.8
1.0m x 1.0m = 10,000	5.5	7.2	7.5	14.0	13.5	14.2	30.0	*44.1	*44.1	86.8	101.4	120.5
1.25m x 1.25m = 6,400	6.8	8.3	6.9	14.1	16.1	15.1	31.4	40.1	40.1	99.0	110.6	136.5
1.50m x 1.50m = 4,444	5.9	6.5	8.1	16.3	15.6	18.5	38.8	*42.5	*42.5	105.2	124.5	142.4
1.75m x 1.75m = 3265	6.9	5.9	7.7	15.1	14.5	17.7	39.8	*41.1	*41.8	108.8	145.1	158.8
2.0m x 2.0m = 2500	7.0	6.6	7.8	14.2	15.8	16.9	35.3	37.5	39.7	111.9	154.9	*167.9
LSD (0.05)		NS			NS			11.1			105.3	

NS = Not Significant * = Significant ** Highly Significant

Table 5: Effect of Locations and Population Density on the Lengths of Petioles of Sweet Annie (Artemisia annua) in three Agro-ecological zones of Nigeria

Tables 5 shows the lengths of petioles per plant. The values increased by the months after planting and the lengths increased with wider spacing. At one and 2MAT there were no significant (P≤ 0.05) differences but there was at 3 and 4 MAT and at 2m x 2m spacing with 111.9cm, 154.9cm and 167.9cm petiole lengths measured for Gombe, Okigwe and Abak respectively.

	At one month after Transplanting: Stem Girths (cm)			2 Months after Transplanting: Stem Girths (cm)			3 Month after Transplanting: Stem Girths (cm)			4 Months after Transplanting: Stem Girths (cm)		
Spacing Density	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak
0.25m x 0.25m = 160,00	0.5	0.5	0.5	0.8	0.9	1.0	0.9	1.0	1.1	1.1	1.2	1.3
0.5m x 0.5m = 40,000	0.4	0.5	0.5	0.7	0.8	0.9	1.0	1.1	1.1	1.1	1.5	1.4
0.75m x 0.75m = 17,777	0.4	0.4	0.4	0.8	0.9	1.1	1.1	1.4	1.3	1.2	1.6	1.5
1.0m x 1.0m = 10,000	0.4	0.5	0.5	0.8	0.8	0.9	1.4	1.6	1.5	1.4	1.9	1.9
1.25m x 1.25m = 6,400	0.5	0.4	0.4	0.7	0.9	1.0	1.4	1.5	1.6	1.4	1.9	2.0
1.50m x 1.50m = 4,444	0.5	0.4	0.5	0.8	0.9	1.0	1.6	1.6	*1.7	1.5	2.0	2.1
1.75m x 1.75m = 3265	0.4	0.5	0.5	0.7	0.9	1.1	1.6	*1.7	*1.8	1.5	2.1	2.3
2.0m x 2.0m = 2500	0.4	0.5	0.5	0.8	0.9	1.0	1.6	*1.7	*1.8	1.6	*2.3	*2.4
LSD (0.05)		NS			NS			0.8			1.1	

NS = Not Significant * = Significant ** Highly Significant

Tables 6: Effect of Locations and Population Density on the Stem girths of Sweet Annie (Artemisia annua) in three Agro-ecological zones of Nigeria

Table 6 presents the stem girths of artemisia across the locations at 1, 2, 3 and 4 MAT. Stem girths sampling was not significant at 1 and 2 MAT in all the 3 locations. However, at 3 and 4 MAT stem girths at 2 x 2m spacing was only significant at Mbato(1.7cm and 2.3cm) and Abak(1.8cm and 2.4cm) respectively.The stem girth was not significant during the same sampling periods at Dadin Kowa.

	Days to 50% Flowering			Fresh whole plant Biomass Per Plant (kg)			Dry whole plant Biomass Per Plant (kg)			Fresh leaf Biomass Per Plant (g)		
Spacing Density	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak
0.25m x 0.25m = 160,00	117.2	125.6	127.3	1.02	1.17	1.19	0.14	0.19	0.25	300.	378.2	398.8
0.5m x 0.5m = 40,000	117.5	126.7	128.4	1.0	1.18	1.21	0.19	0.21	0.29	220	399.6	401
0.75m x 0.75m = 17,777	118.7	128.3	129.5	1.10	1.28	1.25	0.19	0.20	0.30	320	*428	*433
1.0m x 1.0m = 10,000	118.9	128.4	130.3	1.20	1.39	*1.44	0.29	0.29	0.32	330	*469.4	*450.5
1.25m x 1.25m = 6,400	120.4	130.4	132.6	1.19	1.40	*1.48	0.30	0.31	*0.37	405.1	499.5	*535
1.50m x 1.50m = 4,444	121.6	131.6	*135.7	1.21	*1.42	*1.50	0.34	*0.36	*0.39	*452.5	* 511.6	*501
1.75m x 1.75m = 3265	121.5	131.7	*136.8	1.25	*1.48	*1.52	0.33	*0.38	*0.40	*461	*510	*520
2.0m x 2.0m = 2500	121.6	132.0	*137.0	1.30	*1.50	*1.53	0.34	*0.39	*0.40	*455	*535	*540
LSD (0.05)		(15.40)			0.33			0.21			200.1	

NS = Not significant; * = Significant; ** = highly significant

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Tables 7: Effect of Locations and Population Density on the Biomass Yields of Sweet Annie (Artemisia annua) in three Agro-ecological zones of Nigeria

Tables 7 shows days to 50% flowering, fresh and dry whole plant Biomass, and fresh leaf biomass across Gombe, Okigwe and Abak locations. Spacing 0.25m x 0.25m giving plant population of 160,000 in Gombe location significantly (P $\leq$ 0.05) came earlier by flowering at 117.2 days after transplanting while 137.0 days was recorded for Abak location; coming least for days to 50% flowering. In general, the counting of flowering days does not include the two months stay in the nursery. Thus, the range of 117.2 – 137 days giving 3.9-4.5 months when added to two months in the nursery give about 6 month life cycle earlier reported by Diemer and Griffee(2006). This also agrees with Kew (2008) report that Artemisia life cycle in longer in Asia while in Europe and America it is six month. That these plants complete their life cycle across the location before the dry season sets in suggestively indicates Artemisia to be day neutral plant in Nigeria. Fresh whole plant biomass was significantly (P $\leq$ 0.05) higher in wider spacings than in lower spacings . The same for dry whole plants biomass and fresh leaf biomass. Highest fresh whole plant biomass per plant records were 1.30kg, 1.50kg and 1.53kg at 2.0m x 2.0m while the least values; 1.02 kg, 1.17kg and 1.19kg at 0.25m x 0.25m were recorded for Gombe, Okigwe and Abak respectively. Dry whole plant biomass per plant were significant (P $\leq$ 0.05) highest at 0.4kg for spacings 1.75m x 1.75m and 2.0m x 2.0m for Abak location.

	Dry green leaf Biomass Weights (g) Per Plant			Dry Green leaf Biomass Per Hectare in (Kg)			Fresh inflorescence Weight (g) Per Plant			Dry Inflorescence Weight (g) Per Plant		
Spacing Density	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak	Gombe	Okigwe	Abak
0.25m x 0.25m = 160,00	92.5	130	110	*14,800	**20,800	**17,600	74	85	95	32.3	39.9	41.1
0.5m x 0.5m = 40,000	111.5	130	120	4460	5200	4800	86	95	90	44.3	49.7	42
0.75m x 0.75m = 17,777	117.5	140	130	2088.7	2488.8	2311.0	92.0	101	110	51	50	45.4
1.0m x 1.0m = 10,000	148.5	159	160.5	1485	1590	1605	101	120	130	55.4	57.5	57.5
1.25m x 1.25m = 6,400	170	*181.1	177.0	1088	1159.	1333	136	144	150	59.6	64.5	68.5
1.50m x 1.50m = 4,444	168.6	168.9	*181	749.3	751	804.4	141.1	165	170	64.3	63.0	71.5
1.75m x 1.75m = 3265	180	*179.0	*188	5877	584.43	613.8	152	175.5	180	61.0	60.1	73.0
2.0m x 2.0m = 2500	177	*180.1	*190.2	442.5	450.25	475.5	160.1	166	*200	66.6	70.3	*75.6
LSD (0.5)		136.7			5725			122.5			51.33	

NS = Not Significant; * = Significant; ** = highly Significant

Tables 8: Effect of Locations and Population Density on the Biomass Yields of Sweet Annie (Artemisia annua) in three Agro-ecological zones of Nigeria

Tables 8 shows dry green leaf biomass per plant, then per hectare, fresh weights of inflorescence and their respective dry weight at various spacing across Gombe, Okigwe and Abak.

Dry green leaf biomass per plant were low at 92.5g;130g and 110g and at 0.25m x 0.25m for Gombe, Okigwe,and Abak location while significant (P $\leq$ 0.05) high dry green leaf biomass records; 177.0g,180.lg and 190.2g at 2.0m x 2.0m spacing were observed respectively for the locations. The hectare yield of dry green leaf biomass was significantly (P $\leq$ 0.05) high in spacing 0.25mx0.25m (giving; 160000 plants/ha) than in 2.0m x 2.0m (giving; 2500 plants/ha) across all the location. At spacing 0.25m x 0.25m (giving; 160,000 plants/ha) significant (P $\leq$ 0.05) high dry green leaf biomass; 6640Kg (i.e 6.64t) /ha, 20,800kg (i.e 20.8t)/ha, and 17,600kg (17.6t)/ha were recorded for Gombe, Okigwe and Aback respectively. A high density of 25plants/m2 was also used in a field experiment in Vietnam which gave a maximum leaf dry matter yield of 5.3t/ha (Woerdenbag et al., 1994a).In India Kumar et,al (2004) and Bina et,al,(2016) reported a range of 42 – 80 kg/ ha of leave yield. Although with significant (p≤0.05) higher values for canopy spread diameters, number of petioles and length, and stem girths (Tables, 3, 4, 5 and 6) treatment 2.0m x 2.0m gave significantly (P $\leq$ 0.05) least dry green leaf biomass ; 442.5kg, 450.25kg and 475.5kg per Hectare across Gombe, Okigwe and Abak respectively. Thus the lower spacing (0.25m x 0.25m) dry green leaf biomass yield is 15-46 times or folds higher than yields in higher spacing (2.0m x 2.0m). As a population trial is a game of number and maximum land use, lower spacing is hereby advised under normal leaf biomas production cultivation practices.

	Podagrica spp		*Dysdercus Spp*		*Bemissia tabacci*		*Asparia armigera*		*Sylepta derugota*		Grass hopper *zenocerus variegatus*	
TREATMENTS	Mean No	Damage Nature	Mean No	Damage Nature	Mean No	Damage Nature	Mean No	Damage Nature	Mean No	Damage Nature	Mean No	Damage Nature
0.25m x 0.25m = 160, 00	0	Nil	0	Nil	0	Nil	0	Nil	0	Nil	0	Nil
0.5m x 0.5m = 40,000	0	Nil	0	Nil	2	Nil	0	Nil	0	Nil	1	Nil
0.75m x 0.75m = 17,777	0	Nil	0	Nil	0	Nil	0	Nil	0	Nil	0	Nil
1.0m x 1.0m = 10,000	0	Nil	0	Nil	0	Nil	0	Nil	0	Nil	0	Nil
1.25m x 1.25m = 6,400	0	Nil	0	Nil	0	Nil	0	Nil	0	Nil	0	Nil
1.50m x 1.50m = 4,444	0	Nil	0	Nil	0	Nil	0	Nil	0	Nil	0	Nil
1.75m x 1.75m = 3265	0	Nil	0	Nil	0	Nil	0	Nil	0	Nil	1	Nil
2.0m x 2.0m = 2500	0	Nil	0	Nil	0	Nil	0	Nil	0	Nil	1	Nil

Leaf defoliation (Ld) Leaf rolling (Lr) Skeletonization of Leaf (Sl) Leaf Punctures (Lp)

Tables 9: Effect of Location And Population Density of Sweet Annie on The Means of Population of Some Major Insect Pests of Vegetables Summarized for Gombe, Okigwe and Abak Locations

Table 9 shows the summarized incidence and nature of damage done by major vegetables insect pests on sweet annie plant across Gombe, Okigwe and Abak locations. There was no significant (p≤0.05) parasitic relationship between sweet annie plants and insect pests as only *Zenocerus variegatus* were seen to perch for a while and then fly away leaving no damage on plants. The plants at present do not seem to have any particular insect or disease problems, though a form of stem canker has resently been seen in East Africa (Dalrymple,2013).

From all indications the camphor like smell of sweet annie attributed to terpeniods/flavoniods present on the leaves and flowers suggestively present in the trichomes of the plants vegetative and reproductive parts reported by Rombauts, (2015; Bina,(2016); appears to deter insects pests from perching to cause damage.

This singular attribute may present sweet annie (*Artemisia annua*) leaf and floral extracts as a potential Biopesticide.

IV. CONCLUSION

Having flowered within six months before the dry season sets in across the various locations, sweet annie is suggestively a day neutral plant in Nigeria.

Wider spacing, unless for selective seed production, breeding study or other research needs is not advisable as smaller spacing gave 15-46 folds of dry green leaf biomass that is obtainable from wider spacing.

Finally, that insect pests DARED to perch on the plants let alone to cause damage suggest that floral and herb extracts holds a lot potential as a bio pesticide.

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