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Effects of Fish Guano and Exogenous Abscisic Acid on Growth and Nutrient Composition of Vegetable Amaranth (A*marantus cruentus* L.) under Moisture Stress and Non-Stressed Conditions for Smallholder Farmers in Kano State, Nigeria

[1] **Aisha Muhammad Aliyu,** [2] **Umar Bello Ahmad,** [3] **Ado Muhammad**

[1, 2, 3] Faculty of Agriculture and Agricultural Technology Kano University of Science and Technology, Wudil Kano, Nigeria

Corresponding Author: **Aisha Muhammad Aliyu**

Abstract

A field trial was conducted during 2022 dry season at Tsuburai Farm Area Kano University of Science and Technology, wudil (Lat 11º58'N and Long 8º25'E) and Bayero University (Lat 11º58'N and Long 8º25'E) Teaching and Research Farm both in Sudan Savannah zone of Northern Nigeria to determine the effect of fish guano and exogenous abscissic acid on growth and nutrient composition of vegetable Amaranth under moisture stress and non-stressed conditions. The experiment was arranged in a Split Plot Design (SPD) and replicated three times to evaluate plant height, number of leaves, leaf chlorophyll, seed yield per plot, yield per hectare and proximate composition at 2,4,6,8 and 10 weeks after transplanting. Treatments combination consist of three periods of stress (0,10 and 20days) which formed the main plots and a factorial combination of 3 levels of fish guano (0, 100 and 200kg^{-1}) and abscissic acid concentrations (0 20 and 50µmolL-1) allocated to the sub-plots. Results revealed that application of Fish_ABA provide evidence of significant differences in growth and nutrient characters compared to control for parameters (plant height, number of leaves, leaf chlorophyll, seed yield per plot, and yield per hectare, percentage moisture, ash, protein, fat, carbohydrate, fiber, nitrogen, phenol, P and K. Based on the results of the study, it can therefore recommend that application of Fish_ABA levels 3(50µmolL^{-1}), 5(100kg^{-1} / 20µmolL^{-1}), 6(100kg^{-1} / 50µmolL^{-1}) and 9(200kg^{-1} / 50µmolL^{-1}) at 20 days water stress are good for adaptation at both Wudil and BUK location.

Keywords: Amaranthus, Fish Guano, Abscisic Acid, Stress and Nutrient Composition

1. Introduction

Amaranth (*Amaranthus cruentus* L.*)* is a leafy vegetable of high dietary value produced and consumed in most parts of subsaharan Africa, particularly Nigeria (Tindall, 1983) [21]. it is easy to grow; it is heat and drought tolerant, and resistant to many diseases. Traditional vegetables can be harnessed to reduce incidence of diet related diseases, provide essential micronutrients and fiber, alleviate malnutrition, and contribute high levels of antioxidants to diets. It is emerging into the forefront among most vegetables because of its remarkable nutrition; higher minerals, (calcium, iron and phosphorous) and carotenoids. It also contains primary proteins called albumin and globulins, which in comparison with prolamins in wheat, are more soluble and digestible. It has been shown that amaranth leaves are excellent sources of protein, with its maximal accumulation in the blossoming phase (Kadoshnikov *et al.*, 2005) [7] (17.2–32.6% from dry weight for various samples). Amaranth seeds contain more protein (14%g) than other crops as corn and rice and contain several essential amino acids (Soriano *et al.*, 2018) [17]. It is high in fiber and low in saturated fat (DPP, 2010) [5]. It is an exceptionally rich source of calcium, iron, vitamin C, and a very rich source of potassium, vitamin A, riboflavin and a rich source of niacin. The nutrient values of Amaranthus per 100%g edible portion as water 85ml, calorie 48%, protein 5g, fat 0.7g, carbohydrates 5g, fiber 1.5g, calcium 250mg, iron 4mg, B-carotene equivalent 1800mg, thiamine 0.1mg, riboflavin 0.3mg, niacin 1.5mg and ascorbic acid 100mg (Aphane *et al.*,2003) [1]. Guano generally refers to deposits of excreta and egg shells of fish and other seabirds, which transform under certain climatic conditions into the homonymous fertilizer (Ewald *et al.*, 2018) [6]. The genesis of guano represents a recent formation which is produced daily by animal excrements especially by seabirds. It consists of 10-12% nitrogen, 10-12% phosphoric acid P_2O_5 and 3% potash K_2O. Organic farming in agriculture preserves ecosystem. It does not involve use of harmful chemicals and fertilizers rather symbiotic life forms are cultured, ensuring weed and pest control and optimal soil biological activity, which maintain fertility. There is also a positive interaction between the combination of organic manures and urea nitrogen (Bocchi and Tano, 1994) [4]. The main reasons for applying organic fertilizers include the organic amendment of the soil and the provision of nutrients to crops (Warren *et al*., 2006) [22].

Fish guano is an organic matter recognized for its high nutritional and agronomical values through maintenance and development of the micro fauna and micro-flora of the soil, essential to the good exchanges of elements between soil and the plant. There is also stimulation of the root development and growth factor. By its sea origins, fish guano is rich in growth substances favorable for developing the roots (rich in phosphorous, vitamins and trace elements) and for strengthening the plants metabolism. The guano of fish had been analyzed and so indicated that feces contained high organic matter, carbon, nitrogen and phosphate. Consequently, the amendment of soil with guano at 20:1 gave highest shoot length, total dry matter, nitrogen content and nitrogen uptake in finger millet and black gram (Shetty *et al*., 2013) [15]. Reports had concluded that amended the soil with small quantity of seabird and fish guano could induce plant growth and raise crop production. Increasing population in third world countries like Nigeria calls for an increased food crop production. Farmers in this part of the world are normally poor and cannot afford the purchase of expensive chemical fertilizers, hence an alternative must be provided for them. The use of fish poops and stress hormone induces dormancy especially buds, underground stem, seeds and is of paramount importance to alleviate plant adapt to stress conditions as well to enhance the sustainability of crop production. Abscisic acid (ABA) promotes the closure of stomata in guard cells to maintain water in plants. Also, researchers reported that seed treatment with ABA can significantly enhance the antioxidant enzymes activity in maize seedlings subjected to water stress. Furthermore, exogenous application of ABA under water stress increased the grain weight in susceptible wheat cultivars.

The use of organic fertilizers and growth regulators on vegetables has been well established in developed countries but it is still in the developing stage in most parts of sub-Saharan Africa, including Nigeria. Lack of growth regulating industries to supply the smallholder farmers in Nigeria has posed serious challenges in the production of amaranth in most parts of the country. Significant improvement in vegetable amaranth production has been achieved in many parts of the world and African countries like Ghana, Kenya, and Zimbabwe from the time world vegetable centre project commenced in 2017, however to this effect, many farmers are not even aware of this organic fertilizers and growth hormones to boost vegetable amaranth production in Nigeria. Promiscuous Amaranth cultivars tolerant to applied fish guano and ABA will help to enhance the production of vegetables in Nigeria. Thus, our research aims to understand the role of fish guano and abscisic acid in drought tolerance, in vegetable amaranth under water stress and to examine the stress response on its nutritional components

2. Materials and method

The study was conducted during 2022 dry season at Tsuburai farm areas Kano University of Science and Technology, wudil (Lat 11°58'N and Long 8°25'E) and Bayero University (Lat 11°58'N and Long 8°25'E) Teaching and Research farm both in Sudan Savannah zone of Northern Nigeria. Treatments combination consist of three periods of stress (0,10 and 20days after transplanting) which formed the main plots and a factorial combination of 3 levels of fish guano (0, 100 and 200kg^{-1}) and abscisic acid concentrations (0 20 and 50µmolL-1) allocated to the sub-plots. The experimental design was Split Plot Design with three replications. The fields were laid out in three replications, in each replication there were three blocks. Each block was 3m in length and 4.5m width making a plot size of 13.5m^2. The spacing of 1.5m between replications and 1m between blocks. Discard between plots was 0.5m. Inter and intra row spacing of 75cmx30cm. The plot length was 35m, and the width of 44.5m giving a total size of 1557.5m^2.

Treatments

1 =control zero fish guano/zero ABA
2 =zero fish guano/20µmolL^{-1} ABA
3 =zero fish guano/50µmolL^{-1}
4 = fish guano at 100kg^{-1} /zero ABA
5 = fish guano at 100kg^{-1} / abscisic acid at 20µmolL^{-1}
6 = fish guano at 100kg^{-1} / abscisic acid at 50µmolL^{-1}
7 = fish guano at 200kg^{-1} /zero ABA
8 = fish guano at 200kg^{-1} / abscisic acid at 20µmolL^{-1}
9 = fish guano at 200kg^{-1} / abscisic acid at 50µmolL^{-1}

Prior to fish guano application, sample of the fish guano was taken and subjected to the laboratory analysis. Chemical properties of the sample were determined using standard procedures as described by (Black, 1965) [3]. The treatments were applied and incorporated according to the level of treatments two weeks after the transplanting. The field was weeded manually by hoe in the morning two weeks after transplanting. The sampled plant height, number of fully expanded leaves, leaf chlorophyll, seed weight and yield per (kg), and nutrient composition were recorded at 2,4,6,8 and 10 weeks after transplanting (WAS) were taken and recorded.

Data collected were subjected to analysis of variance (Genstat) to test significance of treatment effects as described by Snedecor and Cochran (1967) [16]. Significant means were compared using LSD at P≥ 0.05 alpha level.

3. Results

Table 1: Physico - chemical properties of soil (0-30cm in depth) of experimental farm during 2022 irrigation season at Wudil and BUK farm areas in Kano state, Nigeria

Soil properties	WUDIL (0-30cm)	BUK (0-30cm)
Physical composition (%)		
Sand	59.1	64.2
Clay	18.8	16.37
Silt	21.35	19.43
Textural class	sandy loam	sandy loam
Chemical composition		
pH (H_2O)	6.42	7.34
Organic Carbon (g kg)	0.61	0.55
Total Nitrogen (g kg)	0.09	0.08
Available Phosphorous (mg/kg)	11.14	2.39
Exchangeable Base (cmol kg^{-1})		
CA	1.39	1.14
Mg	0.34	0.51
K	0.08	0.07
Na	0.02	0.01
CEC	1.82	1.74

Table 2: Chemical properties of fish guano

Nitrogen	8.69
Phosphates	7
Potassium	8
Sodium	1.44
Calcium	7.51
Organic carbon	nil
Magnesium	2.45

Table 3: Plant Height of Vegetable Amaranth as affected by Fish_ABA and Stress in the Sudan Savanna during the 2022 dry season

	2 WDL	4	6	8	10	2 BUK	4	6	8	10
Stress(days)										
1	22.29b	40.71	65.248	87.02	111.97	28.05	53.5	74.3	109.6	124.1
2	22.86b	42.74	64.90	87.65	108.66	28.22	51.1	83.8	112.4	128.4
3	26.39a	43.14	63.80	85.46	109.62	25.34	50.6	75.2	102.9	128.2
SE±	0.752	1.323	1.780	2.706	2.688	3.33	3.11	5.30	7.80	6.23
Fish_ABA(FA)										
1	19.74b	28.82d	38.84c	45.51b	56.38c	27.83	54.9	79.7	105.9	138.5
2	24.01ab	45.66bc	73.17b	98.05a	130.54b	26.02	52.2	80.0	104.3	130.7
3	26.18a	50.90ab	75.16ab	106.61a	142.90ab	28.26	54.1	70.5	113.3	130.7
4	20.38b	26.83d	36.72c	44.77b	52.70c	28.44	50.5	72.6	109.8	120.8
5	25.70a	42.02ad	73.93b	107.74a	124.46b	28.77	52.9	79.9	109.3	124.5
6	27.23a	55.52a	86.51a	111.58a	142.74ab	24.33	50.3	80.3	108.9	121.8
7	18.88b	28.12d	36.33c	49.44b	63.50c	29.02	53.6	85.4	109.9	126.8
8	24.03ab	45.78bc	77.78ab	103.99a	127.07b	29.16	52.2	78.4	106.6	126.0
9	28.44a	56.18a	83.41ab	112.68a	150.47a	23.00	44.8	73.0	106.9	122.4
SE±	1.302	2.292	3.084	4.687	4.656	4.31	6.19	4.69	4.48	6.63
S*FA	0.7268	0.0932	0.0150	0.8601	0.3378	0.498	0.749	0.025	0.162	0.349

Means followed by unlike letter(s) are statistically significant at 5% level of probability WAT=Weeks after Transplanting, S=stress, FA Fish_ABA

Table 4: Number of leaves of Vegetable Amaranth as affected by Fish_ABA and Stress in the Sudan Savanna during the 2022 dry season

	2 WDL	4	6	8	10	2 BUK	4	6	8	10
Stress										
1	20.86a	27.98	35.81	45.24b	54.94b	21.00	59.2	38.7	56.6	42.6
2	21.60a	28.25	36.91	50.51a	62.53a	19.93	47.2	43.1	75.4	42.9
3	18.59b	25.64	33.61	46.89ab	57.77ab	20.18	45.8	55.7	68.7	52.3
SE±	0.739	0.813	1.012	1.382	1.809	1.410	9.88	8.56	9.38	6.63
Fish_ABA(FA)										
1	20.26ab	25.52ab	31.82c	35.130b	44.52b	14.67	54.9	79.7	105.9	138.5
2	18.94b	25.73ab	33.01bc	52.486a	62.11a	16.17	52.2	80.0	104.3	130.7
3	24.44a	31.467a	41.45a	56.24a	69.56a	17.50	54.1	70.5	113.3	130.7
4	16.37b	23.611b	29.56c	35.53b	42.09b	17.44	50.5	72.6	109.8	120.8
5	19.99ab	25.49ab	34.88abc	53.11a	62.94a	17.67	52.9	79.9	109.3	124.5
6	19.45ab	28.77ab	39.34ab	55.08a	66.76a	17.33	50.3	80.3	108.9	121.8
7	18.178b	25.91ab	31.89c	40.02b	49.47b	19.02	53.6	85.4	109.9	126.8
8	21.04ab	28.59ab	38.89ab	50.01a	60.45a	17.16	52.2	78.4	106.6	126.0
9	24.51a	30.51a	38.94ab	50.28a	67.81a	17.50	44.8	73.0	106.9	122.4
SE±	1.279	1.408	1.472	2.394	3.133	1.14	6.19	4.69	4.48	6.63
S*FA	0.7268	0.0932	0.0150	0.8601	0.3378	0.498	0.749	0.025	0.162	0.349

Means followed by unlike letter(s) are statistically significant at 5% level of probability
WAT=Weeks after Transplanting, S=stress, FA Fish_ABA

Table 5: Leaf Chlorophyll content of vegetable Amaranth as affected by Fish_Aba and Stress in the Sudan Savanna during the 2022 dry season at wudil location

Treatments	Leaf Chlorophyll Content				
	2WAT	4WAT	6WAT	8WAT	10WAT
Stress (S)					
1	22.86	24.42	25.01	29.37	28.26
2	22.80	26.21	26.81	28.59	28.34
3	21.78	25.69	26.99	28.09	27.85
SE±	0.691	1.029	1.061	0.968	1.223
Fish_ABA(FA)					
1	18.32dc	17.54d	20.41d	20.57b	20.97b
2	23.12b	28.13ab	24.69cd	29.83a	228.47ab
3	26.64ab	30.08ab	34.39a	34.26a	33.82a
4	17.18d	21.22cd	19.59d	23.83b	21.96ab

5	22.57bc	27.02abc	26.92bc	30.60a	30.80a
6	28.74a	31.98a	32.94ab	32.23a	32.76a
7	18.20dc	19.76d	18.50d	23.48b	21.93b
8	21.98bc	23.90bcd	29.72abc	32.06a	32.29a
9	25.59ab	29.48ab	29.88abc	31.32a	30.36a
SE±	1.198	1.784	1.838	1.677	2.126
Interaction					
S*FA	0.02	0.181	0.057	0.875	0.711

Means followed by unlike letter(s) are statistically significant at 5% level of probability
WAT= Weeks after Transplanting, S= stress, FA Fish_ABA

Table 6: Seed Yield of vegetable Amaranth as affected by Fish_Aba and Stress in the Sudan Savanna during the 2022 dry season at Wudil location

Treatments	Seed weight ($kgPLot^{-1}$)	Seed Yield ($kgha^{-1}$)
Stress (S)		
1	90.37	66941
2	89.64	66398
3	89.93	66615
SE±	5.177	3835.079
Fish_ABA(FA)		
1	41.00c	30370c
2	93.09b	68955b
3	137.99a	102214a
4	45.27c	33531c
5	111.26ab	82412ab
6	133.66a	99004a
7	39.12c	28979c
8	88.91b	65860b
9	119.52ab	88535ab
SE±	8.967	6642.552
Interaction		
S*FA	0.436	0.436

Means followed by unlike letter(s) are statistically significant at 5% level of probability
WAT= Weeks after Transplanting, S= stress, FA Fish_ABA

Table 7: Seed Yield of vegetable Amaranth as affected by Fish_ABA and Stress in the Sudan Savanna during the 2022 dry season at BUK location

Treatments	Seed weight ($kgPLot^{-1}$)	Seed Yield ($kgha^{-1}$)
Stress (S)		
1	210.0	178288a
2	361.0	166384.0b
3	107.0	87667.0c
SE±	103.4	22452.6
Fish_ABA(FA)		
1	53.4	33180
2	22.3	24649
3	15.1	10461
4	24.4	22187
5	11.81	12133.7
6	20.7	20419
7	28.1	13749
8	37.6	33690
9	13.1	22187
SE±	10.23	105081
Interaction		
S*FA	NS	NS

Means followed by unlike letter(s) are statistically significant at 5% level of probability
WAT= Weeks after Transplanting, S= stress, FA Fish_AB

Table 8: Proximate composition (%) of Vegetable Amaranth as affected by Fish_ABA and Stress in the Sudan Savanna during the 2022 dry season wudil location

TRTS	MOISTURE	ASH	PROTEIN	FAT	CARBOHYDRATE	FIBER	N	PHENOL	P	K
Stress (S)										
1	10.81b	2.65c	16.97a	5.04c	66.91a	3.91b	17.24c	20.52	16.13	15.70b
2	13.87a	4.06b	18.88a	6.89b	67.57a	3.96b	15.80b	20.19	15.02	19.17a
3	13.39a	5.54a	14.46b	8.19a	49.49b	5.10a	17.24a	20.85	12.16	17.62ab
SE±	0.644	0.336	0.837	0.342	0.659	0.312	0.497	0.356	1.259	0.682
Fish_ABA										
1	14.30	2.59	19.26	7.06ab	61.37	4.05	14.76	20.44	16.39	17.51
2	12.40	4.59	18.07	5.89ab	61.02	3.83	16.56	21.67	13.77	19.64
3	12.41	3.64	16.49	6.17ab	61.42	4.98	15.38	20.67	14.96	14.51
4	11.31	4.68	18.44	6.62ab	62.04	3.87	16.79	20.22	13.51	17.79
5	12.09	4.40	19.26	7.03ab	60.19	4.57	16.80	21.44	16.58	17.34
6	12.17	4.22	16.31	6.94ab	62.10	5.122	16.34	20.33	11.93	18.16
7	12.89	4.07	14.32	6.99ab	61.67	3.86	14.37	20.00	14.59	17.91
8	12.16	4.53	14.76	5.47b	61.41	4.82	15.22	19.89	11.98	17.12
9	14.50	4.03	15.29	8.21a	60.70	3.83	14.74	20.00	16.21	17.48
SE±	1.116	0.581	1.449	0.593	1.142	0.541	0.861	0.616	2.181	1.181
Interaction										
S*FA	1.33	0.68	0.86	1.65	0.24	1.03	0.60	1.53	0.44	0.406

Means followed by unlike letter(s) are statistically significant at 5% level of probability
WAT= Weeks after Transplanting, S= stress, FA Fish_ABA

4. Discussion

Plant height (cm) of vegetable amaranth during the 2022 dry season is presented in table 3 at Wudil and BUK locations. At 2 WAT, there was a significant difference in plant at wudil farm area under different stress level, where stress3 (20 days 26.39) interval gave the tallest plant and plants stressed at 5days and control (stress 2 and 1) produced the shortest plants. At 4, 6, 8, and 10 WAT there was no significant differences in plant height as affected by different stress levels. In earlier reports, exogenous application of ABA caused an increase Cd2+ accumulation, decreased biomass and plant height, as well as chlorophyll a, chlorophyll b, total chlorophyll (Liu *et al*., 2017) [8]. Significant effect of Fish_ABA was observed during the sampling periods (2, 4, 6, 8, and 10 WAT). AT 2 WAT, Fish_ABA 5, 6 and 9(25.70, 27.23, 28.44) produces taller plants while 1 and, 7 (19.74, 18.88) gave the shortest plant. At 4 and 6 WAT, plant treated with fish_ ABA 6 and 9 gave the tallest plant and the shortest plant was produced by fish_ ABA 1(control). At 8 WAT, Fish_ ABA 2, 3, 5, 6 8, and 9 produces the tallest plants, while 1, 4, and 7 gave the shortest plant (45.51, 44.77 and 49.44).At 10 WAT, significantly tallest plant was produced by the plant treated with Fish_ABA 9(150.47) and it is statistically as par with plants treated with Fish_ABA 3 and 6, shortest plant was produced by Fish_ABA 1 and 4. Shetty *et al*., 2013 [15] reported the amendment of soil with guano at 20:1 gave highest shoot length, total dry matter, nitrogen content and nitrogen uptake in finger millet and black gram. There was no significant interaction on plant height of vegetable amaranth throughout the sampling period. The effect of Fissh_ABA and stress were found not significant throughout the sampling period at BUK location.

Leafy amaranth number of leaves as presented in table 5 was significantly influenced by stress and Fish_ABA during the 2022 dry season at wudil location. At 2 WAT, there is a significant difference in the number of leaves/ plants, where stress 1 and 2 gave highest number of leaves and stress 3 produced the least (18.59). There are no significant differences in number of leaves at 4 and 6 WAT during the experiment. However, a significant difference in number of leaves/plants was observed during the 8 and 9 WAT sampling period. Where, stress 2 gave higher number of leaves/plants which is statistically at par stress 3 while stress 1 gave the least number of leaves per plant. The effect of stress on number of leaves was not significant for all samples at BUK farm area.

There is a significant difference in number of leaves/plants treated with Fish_ABA, at 2 and 4 WAT, plants treated with Fish_ABA 3 and 9 gave the highest number of leaves which were statistically similar with Fish_ABA 5, 6, 8 while plants treated with Fish_ABA 2, 4 7, and 8 produced the least number of leaves. At 6 WAT, plant treated with fish ABA 3 produced higher numbers of leaves/plants which is statistically similar with plants treated with Fish_ABA 6, 8 and 9 while plants treated with Fish_ABA 1 and 8 produced lower number of leaves/plants. In the 8 and 9 WAT sampling period, higher number of leaves/plants was observed from plant treated with Fish_ABA 2, 3, 5, 6, 8 and 9 while plants treated with Fish_ ABA 1, 4, 7 produced lower numbers of leaves. According to Mentler, (2002) [10], tomato plants that received weekly soil application of earth juice products, fish hydrolates and seaweed fertilizers, guanos were taller and contained greater number of leaves than other treatments. None of the treatments on number of leaves was significant throughout the sampling period at BUK location. All possible interaction between the factors on number of leaves was not significant at all sampling period.

Leaf Chlorophyll content of plant was affected by Fish_ABA and stress periods at wudil location only (Table 5). The result of the experiment showed that there is no significant difference in the leaf chlorophyll content of vegetable amaranth exposed to different stress levels throughout the sampling period. This is line with the work of (Mohammed Mujitaba *et al*., 2020) [11] that the application of Abscisic acid (ABA) to the lettuce plants under Cd2+ stress maintained the contents of chlorophyll and carotenoids at levels that were similar to the control plants. The decreases in the contents of Chl a, Chl b, Chl a+b and carotenoids in the ABA treated plants were only 4.2%, 3.7%, 4.4% and 32.1%, respectively. The contents of Chl a, Chl b and Chl a+b in the sole ABA treated plants were statistically similar to those of the control plants. However, the application of ABA to unstressed plants caused a 50.5% decrease in the content of carotenoids, relative to the control plants.A significant difference in leaf chlorophyll content of vegetable amaranth was obtained from plant treated with Fish_ABA in all the sampling period. Where plant treated with Fish_ABA 6(28.74, 31.98) gave higher chlorophyll content at 2 and 4 weeks after transplanting, which is statistically similar with the result obtained from plants treated with Fish_ABA 3 and 9(2WAT), 2, 3 and 9 (4WAT). At 6 WAT, plant treated with Fish_ABA at 3 levels (34.39) gave more leaf chlorophyll content which is statistically similar to plant treated with Fish_ABA 6; lower chlorophyll was observed in plant treated with Fish_ABA 1 (20.41). At 8 and 10 WAT, plants treated with Fish_ABA 2, 3, 5, 6, 8 and 9 produced more leaf chlorophyll content, whereas Fish_ABA 1 and 7 produced plants with the lowest leaf chlorophyll content. In a study involving two tomato genotypes, the application of different concentrations of ABA increased the contents of chlorophyll and carotenoids under normal growth conditions (Barickman, Kopsell & Sams, 2014) [2]. In another experiment, seed treatment with different concentrations of ABA increased the contents of chlorophyll a, chlorophyll b, total chlorophyll and carotenoids in pea seedlings which were exposed to $Cd2+$ (Lu *et al*., 2018) [9].

The seed yield per plot and per hectare as affected by stress and Fish_ABA obtained from this trial is presented in table 6 and 7. The result of the experiment revealed that there were no significant differences in seed weight and grain yieldha^{-1} among the plants exposed to different level of stress at both wudil and BUK location. In agreement with Mohammed mujitaba (2020) [11], he stated that the root and leaf biomass of plants treated with sole ABA were relatively similar to those of the control plants. However, the application of ABA-inhibitor (fluridone) also decreased the root and leaf biomass of the lettuce plants. Furthermore, the CdCl2 and fluridone (ABA) treated plants had the least BRS (36.4% and 58.3%, respectively) indicating the plants suffered greater stress from Cd2+ and the ABA-inhibitor. The control and ABA treated plants appeared similar in terms of size. However, the leaves and roots of the sole CdCl2 treated plants were greatly reduced in size. Moreover, there was a significant difference in seed yield per plot and per hectare among the plants treated with Fish_ABA. Where Fish_ABA 3(137.99) gave highest yield per plot which is statistically at par with plants treated with Fish_ABA 5 (111.26), 9 (119.52) while fish ABA 7 (39.12) and 1(41.00) gave lowest yield kg per plot. Highest yield kgha^{-1} was obtained from plant treated with Fish_ABA 3 (102214) whereas plants treated with Fish_ABA5 (82412), 9 (88535) gave similar results. Lowest grain yield kgha^{-1} was obtained from plant treated with Fish_ABA1 (30370), 4 (33531) and 7 (28979) at Wudil location only. BUK site was found to be not significant throughout. There is no significant interaction among the treatments tested during the experiment.

The effect of stress on proximate composition of vegetable amaranth(Table 8) was significant, where stress2 level at 5days(13.87%) interval gave more moisture content compared with control (stress1) having the lowest moisture content(10.81%), more ash content of dried amaranth leaves was observed at rehydration period(stress3) at 20days after transplanting(5.54%), stress level 1(control) gave the lowest ash content (2.65%), higher protein content was obtained from plants subjected to stress 2(5days stress 18.88%) and control(16.97%), the lowest was obtained from plant under stress level 3(14.46%). A highest fat content was given by plant under stress3 (8.19%) and lowest was observed from plant on stress level 1(control 5.04%), more carbohydrate content was observed from plants under stress level 1 and 2 and the least was seen in plant under stress level 3(44.49%), highest fiber content was observed in plant under stress 3(5.1%) and least was obtained in plant under stress level 1 and 2(3.9). Higher Nitrogen content was obtained from plant under stress 3(17.24%) while lowest Nitrogen was seen in plant under stress level 1(15.80%), no significant differences in phenol and phosphorus content of vegetable amaranth as affected by stress periods in the research area. Significantly higher potassium content was observed in plants subjected to stress level 3 which is statistically at par with plant under stress level 2(19.17%), while plant under stress level 1(15.70%) gave the lowest potassium content.

There was no significant difference on the effect of Fish_ABA on the percentage moisture, ash, protein, carbohydrate, fiber, nitrogen, phenol, phosphorus and potassium of amaranth leaves during the experiment at both locations.

There was no significant interaction on proximate composition of vegetable amaranth throughout the sampling period. Mohammed *et al*., (2020) [11] reported that the CdCl2 and fluridone (ABA) treatments greatly decreased the contents of the nutrient elements when compared with the control plants. The CdCl2 treatment decreased the contents of Mg, Ca, Zn, Fe and Mn by 41.3%, 31.6%, 54.5% 29.4% and 68.9%, respectively. In most cases, the application of ABA to the unstressed plants maintained the contents of the nutrient's elements to levels similar to the control plants. Although the contents of nutrient elements in the Cd+ABA treated plants were in some cases lower than those of the control plants, they were generally higher than those of the sole CdCl2 treatment. The application of ABA to unstressed plants maintained the contents of the nutrient elements (except Mn) in the leaves to levels similar to the control plants. With the exception of Cu, ABA treatment also decreased the contents of nutrient elements to levels lower than the control plants. In addition, the application of ABA also maintained the activities of antioxidant enzymes at levels lower than the sole CdCl2 treatment. ABA is reported to act in several ways to improve the antioxidant defense system in plant cells (Peleg & Blumwald, 2011) [13]. Exogenous ABA application alleviated Cd 2+ stress in Brassica campestris (Shen, Niu & Deng, 2017) [14] while pretreatment of rice seeds with ABA protected the plants against salt stress (Sripinyowanich *et al*., 2013) [18]. As concluded in Stephen, *et al*., (2013) [19] findings, the contents of carbohydrates, fats, and protein in amaranth provide balanced nutrients with less amount of consumption compared to other cereals. Also, Tagwira *et al*., (2006) [20] reported that consumption of amaranth provides nutritional and health benefits that include general improvement in well-being of severely malnourished children; prevention and improvement of specific ailments and symptoms exhibited by people that were wasted by HIV/AIDS; and increase in their body mass index. Thus, the proximate content of protein, carbohydrate, fat, ash and nitrogen, phosphorous during stress periods showed that the vegetable amaranth in this study was loaded with balanced nutrients that could enhance healthy living and food security.

5. Conclusion

In conclusion, stress at 20days interval and Fish_ABA levels 50µmolL^{-1}, 100kg^{-1} / 20µmolL^{-1}, 100kg^{-1} / 50µmolL^{-1} and 200kg^{-1} / 50µmolL^{-1} contain high level of grain yield and nutrients. Appropriate concentrations of Fish_ABA can enhance plant tolerance to water stress from vegetative up to grain filled stage and promote food safety under stressed conditions. It remains to be ascertained if similar results will be obtained under field conditions where guanos and growth inhibitors are often used as growing medium for cultivation.

6. Recommendations

Based on the results obtained and in comparison, with other researchers' scientific findings it should be suggested to farmers in the northern savannah ecological zone to adopt growing vegetable amaranth at both household and community levels to enhance the nutritional and healthy living status of the populace toward foods security in Nigeria.

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