Impact of sodium azide on maturity, seed and tuber yields in M_1 African yam bean [*Sphenostylis stenocarpa* (Hochst ex A. Rich) Harms] generation

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Mutation breeding has been recognized as a valuable supplement tool to conventional breeding and it has contributed significantly to crop improvement. This study therefore, evaluated the effects of sodium azide (NaN_3) on maturity, tuber and seed yields related traits of African yam bean (AYB) accessions, with the aim of creating genetic variation. Six promising AYB genotypes with traits of early maturity and high yield were selected from previous evaluations across agro-ecological zones in southwest Nigeria. Seeds of AYB were pre-soaked in distilled water at room temperature ($25 \pm 2\ ^0C$) for 6 hours. The pre-soaked seeds were then treated with different NaN_3 concentrations (0.02%, 0.04%, 0.06%, 0.08%) for 9 hours; the control was also soaked for 9 hours in distilled water. The treated seeds were sown in the field for evaluation of M_1 generation. The results obtained revealed that genotypes, NaN_3 concentrations and their interaction, showed significant differences in most of the traits measured. Also, as the NaN_3 concentration increased, germination, flowering, maturity and other yield related traits decreased. However, germination inhibition increased as NaN_3 concentration increased. Hence, NaN_3 was effective in inducing earliness to flowering and maturity, but it hampers seed and tuber yields. TSS 79 accession produced the highest seed yield, when treated with 0.04% concentration of NaN_3, but other genotypes produced very poor seed yields when treated, hence TSS 79 accession is regarded as a good genotype for recommendation for further improvement in mutation studies for increased seed yield. Therefore, NaN_3 is capable of inducing variability in AYB genotypes and can therefore be exploited for the genetic improvement of AYB in breeding programmes.

Keywords: African yam bean, sodium azide, flowering, maturity, seed yield, tuber yield

African yam bean (*Sphenostylis stenocarpa*) (AYB) is one of the under-utilized legumes grown in Nigeria, Central African Republic, Gabon, Zaire and Ethiopia. It produces two consumable parts: the tuber which grows as the root sink and the actual yam beans (seeds), which develop in pods above the ground (Olasoji et al. 2011). The seeds and tubers are of economic importance providing food for humans and livestock. AYB is a good source of protein, containing approximately 29% and 19% crude protein in its grains and tubers, respectively (Adewale and Dumet 2011). The amino acid (lysine and methionine) content in AYB grain is higher than that in pigeon pea, cowpea and bambara groundnut (Uguru and Madukaife 2001). Global food security is being threatened with increasing dependence on a few major staple crops such as cowpea, maize, rice etc. (Ikhajiagbe and Mensah 2012). AYB is a potential crop to mitigate the current alarming reduction in crop diversity and variability, but the present climate change associated with erratic rainfall patterns and high incidence of pests and diseases in the ecosystem, is contributing to low grain yield of AYB in Nigeria. Although, AYB seems to be capable of reducing malnutrition, most of the known accessions are late maturing, as it attains physiological maturity between 6 – 7 months after planting, depending on cultivars (Akinyosoye et al. 2017). It therefore becomes important to breed for early maturing and high yielding varieties that will be adaptable to the various agro-ecologies of Nigeria.

Mutation breeding has been recognized as a valuable supplement to conventional breeding and it has contributed significantly to crop improvement. Presently, 3220 mutant cultivars have been developed in over 220 crop species through mutation and released to

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farmers all over the world (Bado et al. 2015). Chemical mutagenesis (the non-GMO approach) is a simple approach to create mutation in plants for the improvement of agronomic traits (Roychowdhury and Tah 2011). Sodium azide (NaN_3) has been regarded as one of the most powerful mutagens in crop plants and the mutant plants produced by the treatment of sodium azide are capable of surviving under various adverse conditions and have improved yields, increased stress tolerance, longer shelf-life and reduced agronomic input, in comparison to their normal parents (Khan et al. 2009).

Presently, there is no known registered and released variety of AYB in Nigeria. Some accessions are only found in the hands of old farmers (Saka et al. 2004; Adewale et al. 2012; Ojuederie et al. 2014), thus making it vulnerable to extinction. Also, information regarding research activities on the use of mutation breeding for the genetic improvement of legumes, especially AYB is scarce in Nigeria This study therefore, evaluated the effects of the mutagen (sodium azide) on maturity, tuber and seed yield related traits of African yam bean accessions, with the aim of creating genetic variation among the AYB genotypes

Materials and methods

Selection of AYB accessions for the experiment

Six promising AYB accessions selected for their earliness to maturity and high yield traits/ characteristics from previous evaluations (unpublished) across locations in southwest Nigeria were selected for the study. The list of the accessions and source of collection are presented in Table 1.

Table 1: List of the accessions of African yam bean and source of collection

Accession name	Source
AYB 94	IAR&T
AYB 61	IAR&T
TSS 79	IITA
TSS 62	IITA
TSS 3	IITA
NGB01349	NACGRAB

IAR&T: Institute of Agricultural Research and Training, Ibadan, Nigeria; IITA: International Institute for Tropical Agriculture, Ibadan, Nigeria; NACGRAB: National Centre for Genetic Resources and Biotechnology, Ibadan, Nigeria

Seed treatment

For each AYB genotype, 500 dry seeds (12% moisture content) were divided into five parts to obtain 100 seeds per treatment. The seeds were soaked in distilled water at room temperature (25 ± 2^0C) for 6 hours to soften the seed, thereafter excess water was drained. Seeds were then submerged in solutions containing four different concentrations of sodium azide (NaN_3), 0.02%, 0.04%, 0.06% and 0.08% for 9 hours. The untreated seeds (0%) were also submerged in only distilled water for 9 hours to serve as a control (Sheikh et al. 2012; Raina et al. 2020). A phosphate buffer was used to maintain the sodium azide pH at 3.7. Thereafter, seeds were thoroughly washed in running tap water to remove the residual mutagen from the seed surfaces and then spread on and covered with Whatman 1™ filter paper, so as to surface dry the seeds (Akinyosoye 2020).

Field evaluation

M_1 generation was evaluated during the 2020 cropping season at the experimental field of Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria.

The experiment was laid out in a randomized complete block design with three replications. The plot size was 5 m by 5 m and the crops were planted at the spacing of 1 m by 1 m between and within the rows, respectively. Two seeds were planted per stand with the aim of having 25 stands per plot and 50 plants per plot. Weeds were manually managed. Pest infestations were first noticed on the plants at the reproductive stage and were controlled by using cypermethrin with active ingredient: (200 g/l pyrethroid) E.C (NPIC, 1988) mixed in a knapsack sprayer with fungicide powder benlate, with active ingredient 50% methyl 1-(butylcarbamoyl-2-benzimidazolecarbamate), manufactured by DuPont company, Wilmington, Delaware, U.S.A. Data were collected on germination characters are as follows:

Percentage (%) germination of each plot was calculated:

$$\frac{\text{Number of germinated seed}}{\text{Total number of seeds planted}} x\ 100$$

Inhibition germination percentage was determined:

$$\frac{\text{\%Germination of untreated} - \text{\%Germination of treated}}{\text{\%Germination of untreated}} x\ 100$$

Data were also collected on days to first flowering, days to 50 % flowering, and days to 70% physiological maturity to determine the time to maturity. Yield related traits (number of seeds per pod, number of pods per peduncle, number of pods per plant, number of pods per peduncle, pod weight per plant, pod length, seed yield per plant and tuber yield per plant) were measured according to the guide on AYB descriptors (Adewale and Dumet 2011). Data obtained were subjected to analyses of variance (ANOVA). Differences between the treatments were separated using Duncan Multiple Range Test at 5 % or 1 % levels of significance. Pearson correlations between pair of seed and tuber yields with seed germination traits and other agronomic traits were estimated using Statistical Tool for Agricultural Research (version 2.0.1, 2013 – 2020).

Results and discussion

Analysis of variance for seed germination characteristics, flowering, maturity and yield related characteristics in AYB as affected by genotype, varied concentrations of sodium azide and their interactions

Table 2 shows the seedling germination traits, flowering, maturity, seed and tuber yields of African yam bean (AYB) genotypes were significantly different ($P \leq 0.01$). Also, varied concentrations of NaN_3 had significant effect on all the agronomic and yield related traits measured in this study, excepted days to 50% flowering. Similarly, interactive effect between genotypes and varied concentrations of NaN_3 were significant for most of the traits measured, with the exception of peduncle length, number of peduncles, pods per plant, pod length and 70% physiological maturity. This indicates that performance of the AYB for most of the traits measured in this study may be attributed to their inherent genetic make-up, varied NaN_3 concentrations and their interactions. This is in agreement with the report of others on different crops (Wannajindaporn et al. 2014; Akinyosoye 2020).

Table 2 also shows that a high degree of genotypic variations existed in most of yield components among the AYB genotypes evaluated in this study as reflected by the coefficients of variation (CV), where pod length had the highest CV (113.1%), while the lowest CV was obtained in days to 50% flowering (3.8%). Thus, the high CVs (> 50%) obtained in seed yield per plant and in most of yield components, would facilitate effective selection for grain yield improvement in AYB mutation breeding programmes, whereas low CVs (<50%) obtained in all of seed germination characteristics, flowering and maturity in this study, pointed out that aforementioned traits could be further improved through introduction, selection, hybridization and recombination.

Table 2: Combined mean squares for seed germination parameters, flowering, maturity and yield related characteristics in African yam bean as affected by genotype, varied concentration of sodium azide and their interactions

	Df	GP%	PGI%	DFF	D50F	MAT	SYPP (g)	TYPP (g)	POPEP	PEPP	POPP	POL (cm)	SPPO	POWPP (g)
Genotype (G)	5	4217.11**	3859.71**	9284.17**	10389.50**	440.02**	321.87**	4790.77**	8.55**	55.36**	238.88**	424.21**	145.90**	1550.17**
Concentration (C)	4	13084.44**	21818.38**	9598.73**	10566.04	558.40**	755.18**	4679.38**	3.81**	47.77**	173.32**	294.17*	127.09**	2021.35**
G x C	20	267.11*	549.31**	2991.26**	3275.50**	8.32	170.37**	1722.91**	1.07**	8.88	33.61	96.63	35.58*	493.90*
Error	58	152.14	188.28	14.29**	12.73**	13.00	47.13	270.95	0.69	7.07	22.94	77.95	20.51	229.47
Mean		33.20	59.82	106.54	111.73	184.00	6.49	16.75	1.61	5.22	9.59	7.81	5.19	14.09
SE(0.05)		1.30	1.43	0.39	0.37	0.38	0.712	1.76	0.087	0.29	0.52	0.94	0.48	1.59
CV%		38.41	22.38	4.23	3.81	4.50	105.86	98.27	52.01	50.97	49.96	113.11	87.27	107.52

*, ** Significant at ($P \leq 0.05$) and ($P \leq 0.01$) respectively; GP%: percentage germination; PGI%: percentage germination inhibition; DFF: days to first flowering; D50F: days to 50% flowering; MAT: days to 70% physiological maturity; SYPP: seed yield per plant; TYPP: tuber yield per plant; POPEP: number of pods per peduncle; PEPP: number of peduncles per plant; POPP: number of pods per plant; POL: pods length; SPPO: number of seeds per pod; POWPP: pod weight/plant; CV: coefficient of variation

Effects of genotype and varied concentration of sodium azide on seed germination traits, flowering and maturity

Table 3 shows there were genotypic differences in the mean performance of the AYB genotypes for seed germination traits, flowering and maturity. TSS 79 had highest germination percentage (52.67%), with AYB 94 (45.33%) and AYB 61 (43.33%) also having significantly higher germination percentages than the other genotypes. Two genotypes (NGB01349 and TSS 3) flowered and matured earlier than the other genotypes across treatments, both these genotypes attained first flowering within 104–105 days after seeding (DAS), 50% flowering within 108–109 DAS and both reached 70% physiological maturity in 177 DAS. Therefore, genotypic differences for germination traits, flowering and maturity period of the AYB genotypes could be linked to the effects of varied concentration of sodium azide imposed on them.

Effect of varied concentration of NaN_3 showed that as the concentration of NaN_3 increased, germination percentage decreases from 0% to 0.08% concentration, whereas percentage germination of inhibition increased as the concentration of NaN_3 increases (Table 3). The results obtained in this study had been reported in various crops, including maize (Akinyosoye 2020); cowpea (Gnanamurthy and Dhanavel 2014); soybean (Dhanavel et al. 2008); tomato (Adebola 2013); and wheat (Srivastava et al. 2010). The reduction in seed germination and increase inhibition in seed germination in M_1 African yam bean generation due to sodium azide in this study may be attributed to changes in physiological, biochemical and biological processes as the concentration of the sodium azide increases (Akinyosoye 2020). Salim et al. (2009); Srivastava et al. (2011) reported that NaN_3 effect hampered adenosine triphosphate (ATP) biosynthesis resulting in decreased ATP molecules. Thus, all living cells require energy in the form of ATP molecules to perform biological processes, but at low energy; could lead to decrease in ATP molecules availability and translates to reduction in germination rate or growth and development.

Table 3 shows that, varied concentrations of NaN_3 induced early flowering and physiological maturity as the AYB genotypes treated with NaN_3, flowered and attained 70% physiological maturity earlier than the control in this study. Induction of earliness by NaN_3 in the African yam bean evaluated in this study, could be because induced mutation is non-specific as it is a random event, might possibly affect the gene(s) responsible for flowering and maturity as well as yield by switching from yield production to early flowering and physiological maturity; or vice-versa or favour both at the same time. Induction of early flowering in some crops treated with mutagenic agents has been reported (Mensah et al. 2007; Bolbhat and Dhumal 2012; Animasaun et al. 2014).

Table 3: Means of seed germination traits, flowering and maturity as affected by genotype and varied concentration of sodium azide

	Germination percentage (%)						**Percentage germination Inhibition (%)**					
Accessions	**0.0%**	**0.02%**	**0.04%**	**0.06%**	**0.08%**	**Mean**	**0.0%**	**0.02%**	**0.04%**	**0.06%**	**0.08%**	**Mean**
AYB 61	90.00	26.67	33.33	40.00	26.67	**43.33a**	0.00	70.37	62.96	55.56	70.37	**51.85b**
AYB 94	86.67	53.33	53.33	13.33	20.00	**45.33a**	0.00	39.47	35.87	85.19	76.40	**47.39b**
NGB01349	66.67	6.67	6.67	6.00	4.00	**18.00b**	0.00	90.48	90.48	92.00	94.00	**73.39a**
TSS 3	76.67	13.33	7.00	6.67	3.00	**21.33b**	0.00	82.14	91.00	90.48	97.00	**72.12a**
TSS 62	66.67	6.67	6.67	6.00	6.67	**18.54b**	0.00	90.48	90.00	91.50	90.48	**72.49a**
TSS 79	90.00	60.00	40.00	40.00	33.33	**52.67a**	0.00	33.52	56.11	55.19	63.52	**41.67b**
Mean	**79.45a**	**27.78b**	**24.50b**	**18.67b**	**15.61b**		**0.00c**	**67.74b**	**71.07ab**	**78.32a**	**81.96a**	
	Days to first flowering						**Days to 50% flowering**					
AYB 61	113.00	103.67	107.67	105.67	103.33	**106.67a**	117.00	106.33	111.67	112.00	109.00	**111.20a**
AYB 94	117.67	109.67	110.33	106.67	105.00	**109.87a**	121.67	117.33	116.00	114.00	115.00	**116.80a**
NGB01349	108.33	106.00	106.00	99.00	100.00	**103.87b**	112.33	110.00	109.00	105.00	102.00	**107.67b**
TSS 3	109.00	107.00	106.00	104.00	98.67	**104.93b**	111.00	109.00	109.00	111.00	104.33	**108.87b**
TSS 62	110.00	110.00	105.00	105.00	110.00	**108.00a**	117.67	117.00	107.00	109.00	117.00	**113.53a**
TSS 79	109.33	106.33	105.67	105.00	103.33	**105.93a**	121.33	116.67	108.67	107.00	108.00	**112.33a**
Mean	**111.22a**	**107.11b**	**106.78b**	**104.22b**	**103.39b**		**116.83a**	**112.72a**	**110.22a**	**109.67a**	**109.22a**	
	Days to 70% physiological maturity											
AYB 61	201.00	186.00	186.00	186.00	186.00	**189.00a**						
AYB 94	201.00	186.00	186.00	186.00	186.00	**189.00a**						
NGB01349	186.00	177.00	177.00	174.00	170.00	**176.80b**						
TSS 3	186.00	177.00	177.00	175.00	171.00	**177.20b**						
TSS 62	190.00	180.00	185.00	180.00	180.00	**183.00a**						
TSS 79	201.00	186.00	186.00	186.00	186.00	**189.00a**						
Mean	**194.17a**	**182.00b**	**182.83b**	**181.17b**	**179.83b**							

Means with the same letter(s) in the same column or row are not significantly different from each other at $P > 0.05$

Effects of genotype and varied concentration of sodium azide on yield related traits

Genotypic differences also existed in the mean performance of the AYB genotypes for seed and tuber yields as well as yield related traits in this study. Table 4 shows that the genotype TSS 79 recorded the highest seed yield (13.70 g) per plant across treatments. Also, TSS 79 recorded the highest seed yield of 19.67 g per plant when treated with 0.04% concentration of NaN_3, when compared with the control (14.83 g). Two genotypes (AYB 61 and AYB 94) had highest tuber yields with mean values of 38.07 g and 39.00 g per plant respectively, across treatments. The same genotypes (AYB 61 and AYB 94) recorded highest tuber yield of 132.67 g and 94.67 g per plant respectively, in the control treatment, but AYB 61 gave no yields when treated with 0.08% concentration of NaN_3. For the yield related traits, TSS 79 performed better than other genotypes across treatments in this study. The observed genotypic differences had been reported by some researchers who obtained higher yield at a lower dose of sodium azide (Khan and Goyal 2009). Hence, sodium azide has been reported to have caused positive and negative shifts in yield related traits in wheat genotypes (Srivastava et al. 2010).

Effect of varied concentration of NaN_3 on seed and tuber yields per plant showed that the control had the highest mean values of 17.70 g and 44.47 g for seed and tuber yields, respectively, but these decreased to 6.11 g and 12.39 g for seed and tuber yields per plant, respectively at 0.08% concentration. Consequently, other yield contributing traits followed the same trends as observed in both seed and tuber yields. The results obtained are in agreement with the work of Kumar et al. (2009) who reported that chemical mutagens induced physiological damages (injury), gene mutations and chromosomal mutations in the organisms in M_1 generation in terms of lethality, fertility reduction or sterility (reduction in pods and seed yield). Hence, Adamu et al. (2004) suggested that the trend in some characteristics observed in their studies were concentration dependent.

During the experiment it was observed that leaves and tuber size of AYB plants in the field revealed that plant stands of TSS 79 in control treatment had multiple infections, characterized by leaves lesion, yellowish and wrinkled leaves, especially at the reproductive stage. To combat this the plants were sprayed with insecticide and fungicide, this could be responsible for the low seed yield obtained in the control treatment of TSS 79 when compared with the 0.04% concentration (Table 4; Figure 1A). However, it was observed that varied concentration of NaN_3 affected the tuber formation and development, and all of the genotypes in control treatments produced tubers with big sizes, whereas some of the genotypes treated with NaN_3 had tubers with small sizes and some did not produce tubers (Table 4; Figure 1C and 1D). This could be due to inherent genetic potentials of AYB genotype to varied concentrations of NaN_3 and effectiveness of NaN_3 against field pests. This observation corroborated by the findings of Rodriguez-Kabana and Akridge (2003) who reported that application of NaN_3 on green pepper was capable of controlling weeds and soil-borne pests.

Table 4: Means of yield related traits as affected by genotype and varied concentration of sodium azide

	Seed yield per plant (g)						**Tuber yield per plant (g)**					
	0%	**0.02%**	**0.04%**	**0.06%**	**0.08%**	**Mean**	**0%**	**0.02%**	**0.04%**	**0.06%**	**0.08%**	**Mean**
AYB 61	0.67	0.33	4.67	1.67	2.67	**2.00d**	132.67	52.00	5.67	0.00	0.00	**38.07a**
AYB 94	40.39	1.00	0.67	0.00	0.00	**8.41bc**	94.67	27.33	20.00	20.00	33.00	**39.00a**
NGB01349	10.33	1.00	0.00	0.00	0.00	**2.27d**	4.67	3.00	0.00	0.00	20.00	**5.53bc**
TSS 3	25.67	0.00	0.00	2.00	16.67	**8.87ab**	3.00	0.00	0.00	0.00	0.00	**0.60c**
TSS 62	14.33	0.00	0.00	0.00	4.00	**3.67cd**	3.00	0.00	0.00	0.00	0.00	**0.60c**
TSS 79	14.83	12.33	19.67	8.33	13.33	**13.70a**	28.83	12.33	4.00	17.00	21.33	**16.70b**
Mean	**17.70a**	**2.44b**	**4.17b**	**2.00b**	**6.11b**		**44.47a**	**15.78b**	**4.94b**	**6.17b**	**12.39b**	
	Pod length (cm)						**Number of seeds per pod**					
AYB 61	7.67	6.33	13.50	6.67	15.33	**9.90b**	4.67	4.00	8.83	4.00	7.33	**5.77bc**
AYB 94	11.31	13.67	5.22	0.00	0.00	**6.04bc**	7.06	5.00	2.83	0.00	0.00	**2.98c**
NGB01349	14.67	5.33	0.00	0.00	0.00	**4.00c**	10.67	3.33	0.00	7.06	5.00	**5.21ab**
TSS 3	24.67	0.00	0.00	4.33	16.20	**9.04b**	2.83	0.00	0.00	5.33	12.50	**4.13bc**
TSS 62	6.67	0.00	0.00	0.00	0.00	**1.33c**	9.00	0.00	0.00	0.00	3.33	**2.47c**
TSS 79	20.75	15.90	7.33	17.35	21.28	**16.52a**	11.50	10.50	10.33	10.50	9.67	**10.50a**
Mean	**14.29a**	**6.87b**	**4.34b**	**4.73b**	**8.80ab**		**9.70a**	**3.81b**	**3.67b**	**3.31b**	**5.47b**	
	Number of pods per peduncle						**Number of pods per plant**					
AYB 61	2.60	1.33	2.17	2.67	2.67	**2.29a**	14.33	9.00	12.83	14.14	12.00	**12.46a**
AYB 94	2.43	2.89	1.67	1.33	2.33	**2.13a**	13.40	12.56	12.44	10.00	13.00	**12.28a**
NGB01349	2.00	1.33	1.33	0.00	1.33	**1.20b**	14.87	7.00	9.33	0.00	4.00	**7.04b**
TSS 3	2.17	0.67	0.00	0.67	2.17	**1.13bc**	15.22	9.67	4.33	0.00	13.25	**8.49b**
TSS 62	2.00	0.67	0.00	0.00	0.00	**0.53c**	13.00	4.00	0.00	0.00	0.00	**3.40c**
TSS 79	2.62	2.17	2.00	2.70	2.33	**2.36a**	17.15	13.89	14.00	12.87	11.33	**13.85a**
Mean	**2.30a**	**1.51bc**	**1.19c**	**1.23bc**	**1.81ab**		**14.66a**	**9.35b**	**8.82b**	**6.17b**	**8.93b**	
	Number of peduncles per plant						**Pod weight per plant (g)**					
AYB 61	7.93	5.33	7.17	7.53	6.83	**6.96a**	1.33	0.67	20.83	5.33	7.00	**7.03b**
AYB 94	7.57	6.56	6.33	5.17	6.83	**6.49ab**	48.67	8.00	4.17	0.00	0.00	**12.17b**
NGB01349	7.83	3.33	5.33	0.00	2.00	**3.70c**	29.67	1.67	0.00	0.00	0.00	**6.27b**
TSS 3	8.33	5.00	2.33	0.00	7.25	**4.58bc**	49.33	0.00	0.00	3.00	32.50	**16.97b**
TSS 62	6.50	2.67	0.00	0.00	3.20	**2.47c**	37.00	0.00	0.00	0.00	7.33	**8.87b**
TSS 79	8.25	7.61	7.00	6.67	6.00	**7.11a**	29.50	30.17	27.67	46.67	32.17	**33.23a**
Mean	**7.74a**	**5.08bc**	**4.69bc**	**3.23c**	**5.35b**		**32.58a**	**6.75b**	**8.78b**	**9.17b**	**13.17b**	

Means with the same letter(s) in the same column or row are not significantly different from each other at $P > 0.05$

Figure 1A: Diseased leaves of TSS 79 at reproductive stage (control or untreated with NaN_3), before spraying with insecticide and fungicide in the field

Figure 1B: Smooth and disease-free leaves of TSS 79 at reproductive stage (0.04% concentration of NaN_3)

Tubers of AYB 94 with highest tuber weights in the control treatment

Tubers of AYB 94 at harvest (0.08% concentration of NaN_3)

Figure 1: Visual assessment leaves and tuber size of African yam bean in control (untreated) and treatment with Sodium azide (NaN_3)

Correlation between pairs of tuber and seed yields with other yield contributing traits

Pearson correlation between tuber yield per plant and seed yield revealed that a non-significant association existed between them (r = 0.15) (Table 5). This result corroborates the report of Akinyosoye et al. (2017) who reported non-significant and positive correlation between seed and tuber yields in AYB. This phenomenon could be due to competition between the storage sinks (seeds and tubers) to import photo-assimilates, which is a function of environmental factors and strength of the competing sinks (Farrar 1996; Geigner et al. 1996).

Tuber yield was positively and significantly correlated with percentage germination (r = 0.49**), first flowering (r = 0.28**), 50% flowering (r = 0.28**), 70% physiological maturity (r = 0.66**), number of pods per peduncle (r = 0.28**), number of pods per plant (r = 0.24*), and number of peduncle per plant (r = 0.25*), but negatively and significantly correlated with percentage germination inhibition (r = -0.42**). This suggests that high germination percentage, late flowering and maturity, increase in number of pods per peduncle, pods per plant and peduncle per plant contributed to tuber yield. But percentage germination inhibition hampers tuber formation.

Positive and significant relationships were obtained between seed yield per plant and first flowering (r = 0.24*), 50% flowering (r = 0.23*), 70% physiological maturity (r = 0.40**), pod length (r = 0.46**), number of seeds per pod (r = 0.56**), number of pods per peduncle (r = 0.31**), number of pods per plant (r = 0.31**), number of peduncle per plant (r = 0.30**) and pod weight per plant (r = 0.86**), but negatively and significantly associated with percentage germination inhibition (r = -0.49**). Thus, all positive and significant among yield related traits with seed yield, could be used to improve seed yield. Bello and Olawuyi (2015) reported that significant positive correlations between yield and other yield related traits can improve yield, which are quite desirable in plant breeding, because it facilitates the selection process and gains from selection.

Table 5: Pearson correlation coefficients between pairs of tuber and seed yields with seed germination parameters, earliness and other yield related traits

	TYPP	PSG%	PGI%	DFF	D50F	MAT	POL	SPPO	POPEP	POPP	PEPP	POWPP	SYPP
TYPP	1	0.49**	-0.42**	0.28**	0.28**	0.66**	0.05	-0.02	0.28**	0.24*	0.25*	0.03	0.15
PSG%		1	-0.98**	0.46**	0.47**	0.83**	0.47**	0.49**	0.58**	0.63**	0.60**	0.49**	0.51**
PGI%			1	-0.46**	-0.47**	-0.79**	-0.43**	-0.48**	-0.54**	-0.63**	-0.59**	-0.49**	-0.49**
DFF				1	0.99**	0.39**	0.27**	0.24*	0.57**	0.64**	0.59**	0.26*	0.24*
D50F					1	0.40**	0.28**	0.25*	0.57**	0.65**	0.59**	0.26*	0.23*
MAT						1	0.31**	0.29**	0.50**	0.49**	0.47**	0.34**	0.40**
PODL							1	0.80**	0.46**	0.40**	0.39**	0.62**	0.46**
SPPO								1	0.41**	0.42**	0.39**	0.67**	0.56**
POPEP									1	0.82**	0.77**	0.39**	0.31**
POPP										1	0.95**	0.35**	0.31**
PEPP											1	0.33**	0.30**
POWPP												1	0.86**
SYPP													1

TYPP: tuber yield per plant; PSG%: percentage seed germination; PGI%: percentage germination inhibition; DFF: days to first flowering; D50F: days to 50% flowering; MAT: POL: pods length; days to 70% physiological maturity; SPPO: number of seeds per pod; POPEP: number of pods per peduncle; POPP: number of pods per plant; PEPP: number of peduncles per plant; POWPP: pod weight/plant; SYPP: seed yield per plant

Conclusion

Sodium azide was effective in inducing earliness to flowering and maturity, but it hampers seed and tuber yields. TSS 79 genotype produced the highest yield, when treated with 0.04% concentration of sodium azide, but other genotypes produced very poor seed yields when treated, hence TSS 79 is regarded as a good genotype to be recommended for further improvement through mutation studies for increased seed yield. Sodium azide is capable of inducing variability in African yam bean genotypes and can therefore be exploited for the genetic improvement of African bean in breeding programs.

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