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Effect of ethyl methane sulphonate on growth, yield and some physiological parameters of Bambara groundnut (*Vigna subterranea* (L.) verdc) in non - water stressed and water stressed conditions

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Abstract

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is a legume cultivatd majorly for it's seeds and commonly grown by subsistence farmers in sub-Saharan Africa. In order to determine the effect of ethyl methane sulphonate (EMS) mutagen on the growth, yield and some physiological parameters of non-water stressed (NWS) and water stressed (WS) bambara groundnut. It's seeds were treated with five concentrations (0.00 (control), 0.25, 0.50, 0.75 and 1.00% v/v) Ethyl methane sulphonate and were grown under two conditions: non-water stressed and water stressed. Analysis of variance (ANOVA) revealed significant differences ($P \leq 0.50$) in the emergence percentage (6 DAS), germination percentage (7 DAS), plant height (PH), number of leaves per plant (NL), leaf length (LL), leaf width, (LW), relative water content (RWC), chlorophyll a, b and total chlorophyll contents in the non-water stressed and water stressed plants. After rewatering at 8 WAS, highest number of leaves in NWS and WS conditions were observed in 0.75% EMS concentration (229, 189), highest leaf length in NWS and WS plants were observed in 0.50% EMS concentration (9.47cm, 9.13cm). Highest leaf width in NWS and WS plants was observed in 0.25% EMS concentration (4cm, 3.63cm). Highest number of pods per plant (NP) and weight of pods per plant (WP) were observed in 0.75% EMS concentration only in NWS plants. Highest chlorophyll a, b and total chlorophyll content was observed in 1.00% EMS concentration. The result form this study showed that Ethyl methane sulphonate (EMS) mutagen concentration increased the growth, yield and physiological parameters of Bambara groundnut in non-water stressed condition at different doses, however there was no positive effect of EMS on yield in the water stressed plants.

Keywords: Bambara groundnut; Ethyl methane sulphonate; Growth; Mutagen; Yield

1. Introduction

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is an indigenous African legume with high nutritional value and great potential to tackle the problem of food insecurity in Nigeria. It is one of the important but neglected and underutilized annual leguminous crops in Africa [1]. It is cultivated majorly for its seeds which are produced in pods and It is a major source of protein for resourced poor farmers in Nigeria who cannot afford expensive animal protein [2] [3]. Apart from soybeans, Bambara is rated high in protein compared to other legumes and staples. It also contains methionine and lysine which makes its protein more complete than any other bean [4]. It also has the highest concentration of soluble fibre than any bean, which research has shown to reduce the incidence of heart disease and certain types of cancer [5]. It has good nutritional properties and contains rich quantities of polyunsaturated fattyacids, with linoleic acid being the predominant fatty acid [6]. The demand for bambara groundnut is on increase due to the

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increasing awareness of its nutritional value and its uses. It serves as a major supplement for cereal based diet especially for diabetic patients.

Although bambara groundnut is generally considered to be hardy and drought tolerant when compared with other leguminous crops, recent studies shows that low yield and drought has posed a threat to its productivity especially in the semi- arid regions. [7]. [8] reported a decline in its production in the Sahel and Sudan regions of Nigeria due to the problem of drought as compared to two decades ago. The problem might likely persist as it is estimated that by the year 2025, around 1.8 billion people will face absolute water shortage and 65% of the world's population will live under water stressed environments [9]

The unavailability of improved bambara varieties [12] is a major limitation to large scale production in Nigeria with an estimated yield as low as 68.5 - 159.9 kg ha^{-1} whereas bambara groundnut has the potential of producing up to 3 tonnes per hectare [10] [11]. This has been attributed to lack of improved varieties [12]. The crop has received little attention by Scientists, therefore it is cultivated from local landraces as there are no certified varieties of the species bred for specific traits in Nigeria [13]. There is also a great decline in the production of the crop in the Sahel and Sudan Savannah of Nigeria due to the problem of drought [8].The variable and hostile climates in the region have led to annual yields of most rain fed crops including bambara groundnut to be far below their agronomic or genetic potential [7]. There is a shift in cultivation of Bambara groundnut from the drier part of the country where it is believed to have been originated from to the wetter parts of the country, this has reduced its overall production because there are fewer farmers producing the crop in the wetter areas, land clearing is difficult and costly, soils in the wetter areas are more difficult to cultivate as they are heavier and more prone to weeds, more disease problems are encountered in the wetter areas because of the prevalent high humidity.

Drought has also being reported by [14] to be the most important factor that limits crop production in the world. Increasing Bambara Groundnut yield in Nigeria will require developing improved varieties that are high yielding and tolerant to low moisture supply. Attentionis gradually shifting to mutation breeding where ionizing radiations and chemical mutagens are used to induce genetic variability. For improved quality of species mutagens used may cause genetic changes in an organism , break linkages and produce many new promising traits for the improvement of crop plants [15]. About 3,500 varieties have been released across the globe through mutation breeding and majority of the plants released are food crops [15]. The technology is simple, relatively cheap to perform and equally usable on a small and large scale [16]. One of such mutagen is ethyl methane sulphonate (EMS) which has been used to improve drought tolerance in crops like Durum Wheat [17], and to induce genetic variability in crops. The Crops demonstrate various morpho-agronomic and physiological responses to tackle drought stress. The use of drought tolerant crop varieties is the most suitable way of mitigating the impact of drought stress. This research is a mutation breeding research intended to evaluate bambara Groundnut seeds treated with different doses of ethyl methane sulphonate with the aim of determining mutants that are high yielding and can withstand moisture stress to serve as potential parent lines in breeding for drought tolerance in the crop..

2. Materials and Method

2.1. Experimental Location

The experiment was carried out at the experimental field of the Department of Plant Science and Biotechnology , Prince Abubakar Audu University geographically located at the Eastern part of Kogi State in Dekina Local Government Area which is between Latitude 7^0 15′ - 7^0 2 N andLongitude 7^o11-7^0 32′ E. The area has a mean annual temperature, relative humidity and rainfall of 25 ^{0}C, 61% and 1250 mm respectively. The climate presents two distinct seasons: a raining season between April and October and a dry season between November and March each year. The vegetation is typical of a derived Savanna [18].

2.2. Source of seeds

The seeds used in the study is a cream local landrace of bambara groundnut commonly cultivated in Anyigba and called ‘okpa kpipa’. The seeds were collected from a Bambara groundnut farmer in Anyigba. Three kilograms of the seeds was kept in envelope tied in white polythene bag . It was kept in the refrigerator for some days before treating with ethyl methane sulphonate

2.3. Experimental Treatments and Design

The treatment of seeds with EMS was done following the method of [19] with some slight modifications**.** The seeds were treated with five concentrations (0.00 (control), 0.25, 0.50, 0.75 and 1.00 %) of EMS (Sigma, St Louis, USA). Fifty seeds

were subjected to each treatment. The aqueous solution of the different concentrations of EMS were prepared following the method of [19]. The seeds were soaked in distilled water for twelve hours after which they were soaked again in freshly prepared mutagenic solution of the different EMS concentrations prepared (0.00 (control), 0.25, 0.50, 0.75 and 1.00 %) for six hours and kept at room temperature with intermittent shaking. The seeds were then washed in running water to make them free from the residues of mutagen sticking to the seed and they were sown immediately.

2.4. Collection and labeling of planting buckets

A total of 9 black plastic buckets with dimension 0.60 x 0.48m was allocated for each mutagen treatment per drought condition. The buckets were perforated, washed, dried and then filled with soil from the farmland to a height of about 0.40m. The buckets were labelled by tagging the buckets with their labels.

2.5. Experimental Design and sowing of seeds

The experiment was a 2 x 5 factorial experiment : two drought treatments and five ethyl methane sulphonate doses. The drought treatments include

- T1: Non water stressed condition (Plants were rainfed throughout the experiment, in cases whereby rain did not fall after four days, plants were watered with equal quantity of water)
- T2: Water stressed for two weeks during the flowering stage (Plants were rainfed as in T1 but were deprived of water for fourteen days during the flowering period starting from 40th day after sowing)

The seeds were sown in a randomized complete block design with three replicates per treatment and drought conditions. Two seeds were sown per bucket and later thinned to one, two weeks after planting. The buckets were given a spacing of 30cm x 30cm (inter and intra row spacing). During the period of exposure to water stress, buckets were transferred to the constructed transparent polyvinyl roof pavilion with low block walls and cemented floor. The plants were monitored, weeded and sprayed with insecticide at appropriate time during the experimental period. Plants were sprayed with insecticide Malathion 50% EC (S-1,2-bis (ethoxycarbonyl) ethyl O,O-dimethyl phosphorodithioate) and fungicide Eria (triazole, binzimidazole) to control aphids and diseases.

2.6. Determination of growth parameters

Percentage emergence and percentage germination were determined for each treatment at 6 DAS and 7 DAS respectively. The following growth parameters were determined from three plants per treatment and per replication after exposure to water stress (8WAS) : plant height (PH), number of leaves per plant (NL), leaf length (LL), leaf width (LW). The plant height was determined by measuring the plant height from ground level to the peak of the longest leaf. The number of leaves per plant (NL) were determined by counting the number of leaves attached to the plant. A ruler was used to determine leaf length and leaf width.

2.7. Determination of yield parameters

This was determined following the method of [14]. At maturity , the buckets were emptied of the soil and the following yield traits were determined. Number of pods per plant (NP) were determined by counting the total number of pods a plant produced at the end of its life cycle. The weight of the podswere determined in grams using a weighing scale. Diameter of pods were determined using Vernier Caliper.

2.8. Determination of Physiological parameters

The following physiological parameters were determined in non- water stressed and water stressed plants just before re- watering (8WAS) : relative water content, chlorophylls a, b and total chlorophyll contents.

2.9. Relative water content (RWC)

RWC was determined following the method of [7]. Five leaf discs from leaves of two tagged plants per replication were cut using a cork borer (about 11 mm diameter). The leaf discs were placed in pre-weighed vials, sealed and reweighed to derive their fresh weight (FW) before being placed in petri dishes lined with two layers of germinating paper saturated with deionised water. This was sealed with tape to prevent evaporation and left overnight under a light source to allow discs to re-hydrate to their turgid weight (TW). Their dry weight (DW) was obtained after overnight drying at 80ºC for 48h. The leaf RWC was then measured and calculated according to Turner and Begg (1981) as:

$$RWC\ (\%) = [(FW-DW) / (TW-DW)] \times 100\%$$

2.10. Leaf chlorophyll content

This was determined in the Biochemistry lab of Prince Abubakar Audu University, Anyigba. Leaf disks of about 0.25g were used for determination of actual leaf chlorophyll content by photometric methods as described by [21]. Chlorophyll was extracted from the leaf tissue using a buffered 80% aqueous acetone solution and absorbance were measured on the supernatant by a UV 160 IPC spectrophotometer. Chlorophyll content was expressed in Xg chl.g/Fwt, where Fwt denotes fresh weight. Chlorophyll a, b and total chlorophyll was determined using the below formular:

$$\text{Chlorophylla} = 10.3D_{663} - 0.918D_{644}$$

$$\text{Chlorophyll b} = 19.7D_{644} - 3.8D_{633}$$

$$\text{Total Chlorophyll} = 6.4Q_{633} + 18.8D_{644}$$

Where
D_{663}= Value of absorbance at wavelength 663
D_{644} = Value of absorbance at wavelength 644
D_{633}= Value of absorbance at wavelength 633

2.11. Statistical Analysis

Data collected for growth, yield and physiological parameters in all treatments were subjected to analysis of variance (ANOVA) using SPSS Version 22.0. Treatment means were compared using Duncan multiple range test at probability level of 0.05. Simple correlations between growth parameters, yield parameters and physiological parameters were also determined.

3. Result

Significant differences were observed in the emergence percentage at 6 DAS and germination percentage at 7 DAS with the control having the highest values (40.37%, 81.48%)and 0.75% EMS the lowest (20.19%, 57.41%) respectively. The EMS significantly reduced the emergence and germination percentage in the mutagenized population (Table 1).

Immediately after water stress (8 WAS) the highest plant height in both non water stressed and water stressed conditions was observed in control (31.90 cm, 30.77 cm) although it was not significantly different from 0.50, 0 .75 and 1.00% concentrations. The water stressed plants had a shorter plant height than the non water stressed plants. The shortest plant height was observed in 0.50% EMS concentration for both WS and NWS plants (30.80 cm, 27.93 cm) (Table 2).

Table 1 Effect of EMS on emergence and germination percentage of Bambara Groundnut

Treatment	Emergence percentage (6 DAS)	Germination percentage (7 DAS)
Control	40.37±0.52a	81.48± 5.71a
0.25	25.92±0.02d	59.26±0.00c
0.50	33.17±0.23b	61.11±2.61b
0.75	20.19±0.26e	57.41±2.61d
1.00	29.57±0.09c	61.11±13.09b

Values are Mean ± standard deviation, values with different alphabets aresignificantly different at $P < 0.05$ tested by Duncan Multiple range test

For the number of leaves per plant, highest values were observed in the 0.75% EMS concentration in NWS (229) and WS (189) at 8 WAS. The lowest number of leaves was observed in the control both in non - water stressed and water stressed bambara groundnut plants (191,175). (Table 3)

Table 2 Effect of EMS on plant height (cm) of Bambara Groundnut in non-water stress (NWS) and water stress (WS) conditions

Treatment	NWS (8WAS)	WS (8WAS)
Control	31.90 ± 0.83a	30.77 ±0.64a
0.25	31.30 ±1.04ab	29.73 ±0.55ab
0.50	30.80 ±0.21b	27.93 ±1.10b
0.75	31.53 ±1.50a	30.40 ± 0.53a
1.00	31.00 ±2.59a	29.90 ± 1.68a

Values are Mean ± standard deviation, values with different alphabets aresignificantly different ; at P < 0.05 tested by Duncan Multiple Range test

Table 3 Effect of EMS on number of leaves of Bambara Groundnut in non-water stress (NWS) and water stress (WS) conditions

Treatment	NWS (8WAS)	WS (8WAS)
Control	191.00 ± 5.39b	175.00± 3.46b
0.25	196.00± 4.50b	183.00± 7.52a
0.50	204.00± 7.49ab	178.00± 3.74b
0.75	229.00± 3.05a	189.33± 9.72a
1.00	208.00± 9.16ab	85.00± 8.02c

Values are Mean ± standard deviation, values with different alphabets aresignificantly different at P < 0.05 tested by Duncan Multiple Range test

No significant differences were observed in the leaf length of the plants exposed to different concentration of EMS although concentration 0.5% had the longest leaf length in non water stressed plants and in water stressed plants at 8 WAS (9.47.,9.13 cm). (Table 4)

Significant differences were also observed in the leaf width with the highest leaf width observed in 0.25% EMS (4.00cm, 3.63cm) in both non water stressed and water stressed plants at 8WAS,It was significantly higher than other concentrations. (Table 5)

Table 4 Effect of EMS on leaf length (cm) of Bambara Groundnut in non-water stress (NWS) and water stress (WS) conditions

Treatment	NWS (8WAS)	WS (8WAS)
Control	9.40±0.01a	8.53 ± 1.05a
0.25	8.60±0.32ab	8.13 ± 1.04b
0.50	9.47±0.11a	9.13 ± 0.80a
0.75	8.67±0.29ab	8.23 ±0.12ab
1.00	8.33±0.86b	8.23 ± 0.12ab

Values are Mean ± standard deviation, values with different alphabets are significantly different at P < 0.05 tested by Duncan Multiple Range test

Analysis of variance (ANOVA) revealed significant differences in the effect of ethyl methane mutagen on the number of pods produced by Bambara Groundnut in non-water stressed plants and water stressed plants. The highest number of pods in non-water Stressed plants was observed in treatment 0.75% Ethyl methane sulphonate mutagen (51.67) which was then followed by the treatment 0.25% (47.33) which is not significantly different from the Control (47.00). The least number of pods was observed in treatment 0.50% (37.67).

Table 5 Effect of EMS on leaf width of Bambara Groundnut in non-water stress (NWS) and water stress (WS) conditions

Treatment	NWS (8WAS)	WS (8WAS)
Control	3.63 ± 0.32b	3.40± 0.20b
0.25	4.00 ± 0.00a	3.63±0.17a
0.50	3.37 ± 0.12b	3.13±0.15b
0.75	3.80 ± 0.35ab	3.27±0.15b
1.00	3.87 ± 0.23a	3.30 ± 0.30

Values are Mean ± standard deviation, values with different alphabets are significantly different at P < 0.05 tested by Duncan Multiple Range test

In water stressed plants, the highest number of pods was observed in the Control (11.33) which had no treatment and they were significantly different from all other treatments. The least number of pods was observed in treatment 0.25% (1.67). (Table 6)

Table 6 Effect of EMS on number of pods produced by Bambara Groundnut in non-water stress (NWS) and water stress (WS) conditions

Treatment	Non Water Stressed	Water Stressed
Control	47.00b	11.33a
0.25	47.33b	1.67c
0.50	37.67d	7.00ab
0.75	51.67a	4.67b
1.00	43.00c	3.33b

Values with different alphabets are significantly different at P < 0.05 tested by Duncan Multiple Range test

nalysis of variance (ANOVA) revealed significant difference in the effect of ethyl methane sulfonate mutagen on the weight of pods in non-water stressed plants andin water stressed plants. The highest weight of pods in non-water Stressed plants occurred in the treatment 0.75% (123.67g). This was followed by the control (0.00) (122.67g) and then treatment 0.25% (121.00g). The least weight of pods was observed in treatment 1.00% (103.00g).

Table 7 Effect of EMS on weight (g) of pods produced byBambara Groundnut innon-water stress (NWS) and water stress (WS) conditions

Treatment	Weight of pods (Non Water Stressed)	Weight of pods (Water Stressed)
Control	122.67a	18.67a
0.25	121.00a	2.33b
0.50	104.33b	11.33ab
0.75	123.67a	13.33ab
1.00	103.00b	2.00b

Values with different alphabets are significantly different at P < 0.05 tested by Duncan Multiple Range test

The highest weight of pods in water stressed plants was observed in the Control (18.67g) and it was significantly different from treatment 0.25% (2.33g) and 1.00% (2.00g) but not significantly different from treatment 0.50% (11.33g) and 0.75% (13.33g). The least weight of pods was observed in treatment 1.00% (2.00g). (Table 7)

Analysis of variance (ANOVA) revealed significant difference in the pod diameter of non-water stressed and water stressed plants with the Control having the highest pod diameter (1.72cm) and 1.00% EMS the lowest (1.46cm), in non-water stressed plants.

In the water stressed plants the highest pod diameter was observed also in the control (1.48cm) and the least diameter was observed in treatment 1.00% (0.56cm). (Table 8)

Table 8 Effect of EMS on pod diameter (cm) produced byBambara Groundnut innon-water stress (NWS) and water stress (WS) conditions

Treatment	Pod Diameter (Non Water Stressed)	Pod diameter (Water Stressed)
Control	1.72± 0.05a	1.48 ± 0.16a
0.25	1.62 ± 0.12ab	0.78 ± 0.47b
0.50	1.49 ± 0.12bc	1.29 ± 0.04a
0.75	1.51 ± 0.06bc	1.27 ± 0.12a
1.00	1.46 ± 0.08c	0.56 ± 0.24b

Values are Mean ± standard deviation, values with different alphabets are significantly different at P < 0.05 tested by Duncan Multiple Range test

In non-water stressed plants, the highest relative water content was observed in 0.75% EMS (63.38) and the lowest in the 1.00% EMS (49.98) but in water stressed plants 0.75 % gave the lowest relative water content (16.67) and the highest relative water content was observed in 0.25%EMS (49.89) . (Table 9)

Table 9 Effect of EMS on relative water content of Bambara Groundnut innon-water stress (NWS) and water stress (WS) conditions

Treatment	Relative water content (Non- Water Stress)	Relative water content(Water Stress)
Control	50.0000c	38.8900b
0.25	56.5467b	49.8900a
0.50	51.7667c	33.3333b
0.75	63.3800a	16.6667c
1.00	49.9800c	27.7667bc

Values with different alphabets are significantly different at P < 0.05 tested by Duncan Multiple Range test

For the chlorophyll content, it was observed that EMS concentrations of 0.75 and 1.00% significantly increased chlorophyll a, b and total chlorophyll content in both non- water stressed and water stressed bambara groundnut while 0.25 and 0.50% significantly reduced chlorophyll a, b and total chlorophyll contents (Table 10)

Table 10 Effect of EMS on chlorophyll a, b and total chlorophyll content of Bambara Groundnut exposed to water stress

	Chlorophyll	A	Chlorophyll	B	Total	Chlorophyll
Treatment	NWS	WS	NWS	WS	NWS	WS
Control	0.2253c	0.1453c	0.5450c	0.4147c	2.4867c	1.7037c
0.25	0.2050d	0.1327d	0.4820d	0.4420d	2.2333d	1.5333d
0.50	0.2023d	0.0863e	0.4877d	0.2827e	2.2053e	1.0860e
0.75	0.2439b	0.1557b	0.6207b	0.4880b	2.7233b	1.9267b
1.00	0.2633a	0.1863a	0.6550a	0.5133a	2.9433a	2.1833a

Values with different alphabets are significantly different at P < 0.05 tested by Duncan Multiple Range test NWS: Non- water stress.; WS: water stress

4. Discussion

The EMS significantly reduced the emergence and germination percentage in the mutagenized population (Table 1). [22]; [23]; [24] in their study also reported decrease in emergence and germination percentage of cowpea treated with

different doses of EMS. The reduction in emergence and germination percentage in the mutagenized population could be due to the effect of the EMS thereby causing physiological and chromosomal damage [25]. The seeds must have absorbed the mutagen, which subsequently reached the meristematic region and affected the germ cell. There may have been a delay in the onset of mitosis and chromosomal aberration induced enzyme activity such as catalase, lipase and hormonal activity which could have resulted in reduced germination percentage [26].

From the study carried out on the effect of ethyl methane sulphonate mutagen on non-water stressed and water stressed Bambara groundnut, ethyl methane sulfonate mutagen at0.75%significantly increased number of leaves per plant, number of pods produced per plant, weight of pods and relative water content in non water stressed plants while EMS concentration of 0.25 %significantly increased leaf length, leaf width and relative water content in water stressed plants. This agrees with the results of [27] on Cowpea (*Vigna unguiculata* L. Walp) and [28] on legumes who reported that the yield performance of pigeon pea accessions treated with EMS mutagen were significantly improved by the mutagen treatments. In the water stressed plants, plant height, the number of pod, weight of pod, diameter of podall reduced in the treatments used compared to the control. [29] also observed that the yield performance in terms of number of pod, pod diameter, pod weight, number of seed and 100 seed weight was reduced in all treatment as compared to the control plant.

The chlorophyll a, b and total chlorophyll content of bambara groundnut were significantly increased by all EMS concentrations used with 1.00% having the highest chlorophyll content.[30] reported that higher concentration or treatments produced statistically more weighty seeds than low concentrations.

Chemical mutagens, especially the Ethyl Methane Sulphonates (EMS), are used to induce mutations in plants. Through chemical reactions within the genome, EMS affects the DNA molecule. Thus, the mutagenic treatments must have induced a wide range of genetic variability in the crop. According to [31] Mutations can also cause deleterious effects on legume growth and development, such as stunted growth, reduced flowering, seed abortion, or malformed seeds. These can lead to lower yields, lower nutritional value, or reduced marketability of the crops.

From the study carried out, it was revealed that water stress reduced growth, yield and physiological parameters of bambara Groundnut both in the control and mutagenized plants. [7] also reported similar result that Plants stressed during flowering stage had the lowest number of pods, weight of pods and diameter. Water stress during the period of flowering resulted to death of plants and reduced yield. This result are contrary to the findings of [31] and [25] on their findings on legumes under water stress such as black beans, gaba beans, and bambara groundnut. After rewatering the plants resumed flowering stage, reaching maturity with few numbers of pods and matured pods. The numbers of pods, weight of pods and diameter of pods in all treatments was however less when compared to the non-water Stressed plants definitely due to stress induced condition. And probably the seed variety used could not withstand water stress. According to [32], “Brown and Red” landraces respond to water stress better than the “Light–brown” landrace, this suggest an effect of seed color on possible drought tolerance. Drought has also been reported by [14] to be the most important factor that limits crop production in the world.

Therefore the result of this Study on the effect of ethyl methane sulphonate mutagen on growth, yield and some physiological parameter of Bambara Groundnut in non-water stressed and water stressed conditions suggest that EMS mutagen of 0.75% concentration can positivelyincrease the yield performance of Bambara groundnut in non water stressed condition.

5. Conclusion

The result form this study showed that Ethyl methane sulphonate (EMS) mutagen concentration increased the yield of Bambara groundnut in non-water stressed condition. However there was no positive effect of EMS on the yield in the water stressed plants. The studies also revealed that bambara groundnut was affected by water stress as the morphological, yield and physiological parameters studied were all reduced in the water stressed plants.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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