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VEGETATIVE GROWTH, YIELD QUALITY, AND PHYTOCHEMICAL ACCUMULATION OF *Abelmoshus esculentus* L. (MOENCH) INFLUENCED BY PRIMING WITH POTASSIUM NITRATE

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ABSTRACT

Seed priming is a promising technique that can improve the growth and yield of plants under optimum conditions. The specific priming duration and concentration required for adequate vegetative growth, yield quality, and phytochemical accumulation of *Abelmoshus esculentus* need clarification. This study was evaluated under screen house conditions, using a completely randomized design (CRD) approach. The seeds of *Abelmoshus esculentus* were subjected to priming with potassium nitrate for 6 and 12 h duration at a concentration of 0.5 and 1.00 mM while unprimed seeds served as the control. The results revealed that the primed seeds showed improved vegetative growth, yield components, and phytochemical constituents compared to the unprimed control seeds. This observation was irrespective of the priming duration and concentration of potassium nitrate used. Moreover, seeds primed for a 6 h duration at 1 mM were significantly higher in yield, fruit mineral, and phytochemical constituents compared to other treatments. At 12 h priming duration, seeds primed in 0.5 mM of potassium nitrate had higher growth and yield than at 1 mM. Priming with inorganic salts such as KNO_3 induces faster growth and maximum crop yield of *Abelmoshus esculentus*. Priming for a short duration (6 h) and at high concentration is sufficient to enhance the growth process and increased yield of *Abelmoshus esculentus* and has practical implications in the production of *Abelmoshus esculentus*.

Keywords: Mineral ions, Okra, Potassium nitrate, Priming duration, Priming Concentration, Phytochemicals.

INTRODUCTION

Priming seeds with inorganic chemicals is considered one important way to improve crop growth and productivity under optimum conditions (Johnson *et al.*, 2005). Of the different priming agents, potassium nitrate (KNO_3) is an inorganic compound with a unique source of potassium and nitrogen which is of nutritive value to the health and productivity of crops (Mohammadi, 2009). Potassium nitrate is crucial in many metabolic processes in small or large quantities. It enhances growth, initiates flowering and fruiting, increases yield, and improve yield quality in vegetables and field crops (Harris, 2007). It also regulates the biochemical and developmental processes of crops such as bud, shoot, and root growth (Matakiadis *et al.*, 2009), seed germination (Farooq *et al.,* 2008), plant–water relations, photosynthesis, stomatal conductance (Srivastava *et al.*, 2010), fruit ripening and senescence (Srivastava and Bose, 2012).

Several studies confirmed that seed priming offers many benefits, such as rapid emergence, stand establishment, higher water use efficiency, increasing growth, and uniformity in emergence. Other benefits include breaking of seed dormancy, initiation of reproductive organs, better competition with weed, early flowering and maturity, resistance to environmental stresses (such as drought and salinity) and diseases (Sallam, 1999; Ghana and Schillinger, 2003; Subedi and Ma, 2005; Farhoudi *et al.*, 2007; Ghassemi-Golezani, *et al.*, 2008). Meanwhile, seed priming with potassium nitrate has been used for seedling establishment, improving seed vigor, growth, and yield of some crops (Srivastava and Bose, 2012).

Abelmoshus esculentus (okra) is one of the most widely grown vegetable crops in the tropics, subtropics, and some parts of the temperate region due to its high economic importance (ECHO, 2003). *Abelmoshus esculentus* fruits and seeds contain fat, carbohydrates, proteins, and ascorbic acid (vitamin C) (Adeboye and Oputa, 1996). The essential and non-essential amino acids in *Abelmoshus esculentus* fruits are comparable to those in soybean seeds. Hence, it plays a vital role in the human diet, especially in geriatrics and pediatrics. Young immature fruits of *Abelmoshus esculentus* contain carbohydrates, proteins, and vitamin C in large quantities, and the pods are a good source of flavonoids and antioxidants like beta carotene, xanthein, and lutein (Dilruba *et al.,* 2009). However, the poor establishment and uneven germination of the okra seed are the main hurdles in early spring planting. Therefore, this crop requires an improvement in its vegetative growth and yield quality under optimum conditions (Pandita *et al.,* 2010). Many techniques have been developed to improve seedling establishment, growth, and yield of okra. Priming with inorganic compounds like KNO_3 may offer a promising technique for its growth and yield and quality. Varying the concentration of KNO_3 at priming duration (Muhammad *et al*., 2015) could be a promising technique for improving the growth and yield of *Abelmoshus esculentus* under optimum conditions. Plants can exhibit their physiological rhythmic behavior from the duration of between 6 and 12 h (Taiz and Zeiger, 2006). Also, Paul and Choudhury (1991) reported that seed soaking with 0.5 to 1% K_2SO_4 or KCl significantly increased plant height, yield, and yield components in wheat genotypes. Therefore, the present study was designed to investigate the effects of priming duration and concentration on improved vegetative growth, yield quality, and phytochemical accumulation of *Abelmoshus esculentus*.

MATERIALS AND METHODS

Priming of Seeds with Potassium nitrate

Abelmochus esculentus seeds of accession number NHOK0049 were utilized in this experiment. The seeds were obtained from National Horticultural Research Institute (NIHORT), Idi-Ishin, Ibadan, Oyo State, Nigeria. The seeds were first decontaminated by soaking for 10 min in 5% sodium hypochlorite. Thereafter, the seeds were soaked in 0.5 and 1 mM of potassium nitrate (KNO_3) for 6 and 12 h, amended with Tween 20 (polyoxyethylene sorbitan monolaurate) to facilitate the adherence to the seeds, and air-dried at room temperature for 2 h (Farhoudi *et al*., 2007). After the stipulated period, the seeds were then air-dried at room temperature for 24 h to restore the initial moisture content of seeds before sowing.

Raising of Seedlings

The seedlings of *Abelmochus esculentus* were raised in a screen house to minimize intrusive factors. The temperature range of the screen house is 28-32 °C, while relative humidity ranges between 50-55%. Thirty planting bags were obtained (9 cm in diameter and 7.5 cm in height). These planting bags were filled with 10 kg of collected soil. Primed seeds of *Abelmochus esculentus* were sown at a depth of 4 mm below the soil in planting bags with loamy soil, at the rate of three seeds per planting bag. Before and after seed sprouting, the planting bags filled with soil and seed sown were supplied with 500 mL of tap water every morning and evening. Thereafter, the seedlings were divided into five parts. They comprised unprimed seedlings (control), seedlings primed with 0.5 mM of KNO_3 for 6 h, seedlings primed with 0.5 mM for 12 h, seedlings primed with 1 mM of KNO_3 for 6 h, and seedlings primed with 1 mM potassium nitrate for 12 h. The experimental setup was established in a split-plot factorial Design (CRD) with six replications.

Vegetative Growth Parameters

Sampling was carried out five days after seedling establishment. Growth parameters, such as shoot height, the number of leaves, length of internodes, the number of buds, and leaf length and width with a correction factor (0.75) (used to find out the leaf area) were determined, at every interval of five days. Crop growth rate**,** leaf area ratio, relative growth rate, and net assimilation rate were determined according to Olowolaju and Adelusi (2017) using leaf area and dry matter data as indicated;

$$\text{Crop growth rate} = \frac{(W2-W1)}{(t2-t1)}$$

$$\text{Leaf area ratio} = \frac{(A2-A1)\,(\ln W2-\ln W1)}{(W2-W1)\,(\ln A2-\ln A1)}$$

Relative growth rate = NAR × LAR;

$$\text{Net assimilation rate} = \frac{(W2-W1)(\ln A2-\ln A1)}{(A2-A1)(t2-t1)}$$

Where W1and W2 is weight at t1 (4th week after sowing) and t2 (6th week after sowing), A1 and A2 is the respective leaf area at t1 and t2, NAR=Net assimilation rate, LAR= Leaf area ratio.

Yield Components

The *Abelmoshus esculentus* plants were randomly picked from respective regimes, separated into shoot, leaf, and root, weighed with a digital weighing balance (model SES620C, Saffron, Industrial Ltd., China), and thereafter oven dried in a Gallenkhamp oven (model DZF-6020, Zhengzhou Keda Co., Ltd., China) at 45 °C for 72 h. The total fresh and dry weight was determined by adding the leaf, root, and shoot fresh and dry weight. At the reproductive stage attained at 7 weeks after sowing, the number of flowers was counted from each regime and recorded. After harvest, the number of fruits, number of seeds in fruits, and fruit weights were also determined.

The harvested fruits of *Abelmoshus esculentus* were air-dried for a week, crushed into powder at 105ºC on a block in HNO_3/H_2O_2 solution, and analyzed for concentrations of mineral ions such as calcium, magnesium, potassium, sodium, iron, and zinc using the standard method of analysis of AOAC (2000). The Qualitative analysis of the presence or absence of phytochemicals such as glycosides, resins, saponins, phlobatannins, flavonoids, sterols, phenols, sterols, carbohydrates, alkaloids, and terpenoids was carried out following the standard procedures (Sofowora 1982; Ghani 1998; Olowolaju 2019).

Statistical Analysis

The values collected for each vegetative growth and yield parameters at each interval of the sampling period were subjected to means using Microsoft Excel 2007 version. Where appropriate, data were subjected to ANOVA in SAS version 9.2. Where interaction does not exist, means were separated using a *t*-test at a 5% alpha level.

RESULTS

Vegetative growth parameters of *Abelmoshus esculentus* influenced by priming with potassium nitrate

The KNO_3 priming concentration and duration significantly increased the vegetative growth parameters of *Abelmoshus esculentus*. In general, maximum shoot height, leaf number, leaf area, internode length, and the number of buds of *Abelmoshus esculentus* were obtained in seedlings primed for 6 h at a concentration of 1 mM. For all the vegetative growth parameters, 6 h primed seeds were significantly higher than those primed for 12 h. There were variations in the value recorded for shoot height, leaf number, leaf area, internodes length, and the number of buds for 12 h primed at 0.5 and 1 mM, meanwhile, maximum shoot height, leaf number, leaf area, internode length and the number of buds of the 6 h primed seeds at 1 mM was significantly higher than 0.5 mM (Table 1).

Table 1: Growth parameters of *Abelmoshus esculentus* influenced by priming with potassium nitrate.

	Treatments				
	0.5 mM		1 mM		
Growth Parameters	6 h	12 h	6 h	12 h	Unprimed (control)
Shoot height	29.77b**	28.53c*	30.42a**	26.30d*	11.09e
Leaf number	4.85b**	4.70bc	8.94a**	4.90b	4.73c
Leaf area	92.85b**	86.44d*	103.00a**	91.76c*	13.51e
Internode length	3.04a	2.93b	3.12a	2.89b	1.93c
Number of buds	2.95b**	2.03b*	3.15a**	3.10a*	2.00c

Mean values with letters represents significant difference among treatments at P≤0.05. ** indicate significant differences between 6 h durations, *indicate significant differences between 12 h durations.

The maximum crop growth rate, net assimilation rate, and relative growth rate were obtained in 6 h primed with KNO_3 at concentration of 0.5 mM. The highest values for leaf area ratio were observed in 6 h primed with KNO_3 at a concentration of 1 mM. Significant differences (P≤0.05) were observed in all the growth indices of *Abelmoshus esculentus* at 6 h and 12 h duration primed at 0.5 and 1 mM (Table 2).

Table 2: Growth indices of *Abelmoshus esculentus* influence by priming with potassium nitrate.

	Treatments				
	0.5 mM		1 mM		
Growth Indices	6 h	12 h	6 h	12 h	Unprimed (control)
Crop growth rate	14.25a**	14.05a*	11.10b**	7.55c*	9.70d
Leaf area ratio	53.18c**	53.71c*	81.38a**	63.18b*	49.16d
Net assimilation rate	0.66a**	0.65a*	0.52b**	0.45c*	0.35d
Relative growth rate	35.09a**	34.91b*	32.85c**	28.43d*	17.21e

Mean values with letters represents significant difference among treatments at P≤0.05. ** indicate significant differences between 6 h duration, *indicate significant differences between 12 h duration.

Yield components of *Abelmoshus esculentus* influenced by priming with potassium nitrate

All the yield components of *Abelmoshus esculentus* (total fresh and dry weight, number of flowers, fruits, and seeds in the fruit, and fruit weight) were highest at 6 h primed with KNO_3 at 1 mM. The mean values comparisons pointed out that for the 6 h primed duration, the maximum number of flowers, fruits, and seeds in the fruit, and fruit weight were obtained at 1 mM, while for 12 h primed, the highest values for these parameters were obtained at 0.5 mM. A significant difference (P≤0.05) was observed among the yield components at different concentrations and duration (Table 3).

Table 3: Yield components of *Abelmoshus esculentus* influenced by priming with potassium nitrate.

	Treatments				
	0.5 mM		1 mM		
Yield Components	6 h	12 h	6 h	12 h	Unprimed (control)
Total fresh weight	34.40a	27.70b*	34.70a	24.20*c	17.50d
Total dry weight	5.90b**	5.50b*	6.60a**	4.80c*	2.41d
Number of flowers	3.70b**	3.40b*	4.70a**	2.30c*	1.3d
Number of fruits	5.20a**	5.00b*	4.60c**	3.80d*	2.50d
Number of seeds in fruit	9.40b**	8.67c	12.70a**	8.98c	8.00d

Mean values with letters represents significant difference among treatments at P≤0.05. ** indicate significant differences between 6 h durations, *indicate significant differences between 12 h duration

Mineral constituents of *Abelmoshus esculentus* influence by priming with potassium nitrate

The mineral constituents of *Abelmoshus esculentus* fruit were significantly influenced by priming concentrations with KNO_3 at different durations. Among the treatments, calcium and iron contents were highest in 6 h primed at 0.5 mM while magnesium, potassium, sodium, and zinc contents were highest in 6 h primed at 1 mM. The mean value comparisons showed that the mineral contents of *Abelmoshus esculentus* fruit were higher in 6 h primed duration at 1 mM except for calcium and iron. Also, mineral contents of *Abelmoshus esculentus* fruit were higher in 12 h primed at 1 mM than those obtained in 0.5 mM except for magnesium. Meanwhile, the calcium contents of *Abelmoshus esculentus* fruit were the same in 12 h primed at 0.5 mM and 1 mM. A statistical difference ($P \leqslant 0.05$) was observed among the mineral contents of *Abelmoshus esculentus* at different concentrations and duration (Table 4).

Table 4: Mineral constituents of *Abelmoshus esculentus* influenced by priming with potassium nitrate.

	Treatments				
	0.5 mM		1 mM		
Mineral Constituents	6 h	12 h	6 h	12 h	Unprimed (control)
Calcium	0.64a**	0.40c	0.58b**	0.40c	0.24d
Magnesium	0.46b**	0.43b*	0.51a**	0.38c*	0.39c
Potassium	2.82b	2.01c	2.96a	2.89b	1.74d
Sodium	2.25c**	2.26c*	3.49a*	3.26b**	2.22c
Iron	0.18a**	0.12d*	0.17ab**	0.16b*	0.11c
Zinc	0.07b**	0.062c	0.09a**	0.064c	0.054d

Mean values with letters represents significant difference among treatments at $P \leq 0.05$. ** indicate significant differences between 6 h duration, *indicate significant differences between 12 h duration.

Phytochemical Constituents of *Abelmoshus esculentus* influence by priming with potassium nitrate

The phytochemical constituents of *Abelmoshus esculentus* fruit were influenced by KNO_3 priming. It indicated that resins, flavonoids, carbohydrates, phenols, and alkaloids were present in *Abelmoshus esculentus* fruit in all the treatments. Resins and alkaloids were weakly present at 6 and 12 h primed at different concentrations of KNO_3, phenol was weakly present at 6 h primed, but notably absent at 12 h primed at different concentrations. Meanwhile, flavonoids and carbohydrates were moderately present at 6 h primed and weakly present at 12 h primed at 0.05 mM. In addition, flavonoid was strongly present at 6 h primed duration at 1 mM (Table 5).

Table 5: Phytochemical constituents of *Abelmoshus esculentus* as influenced by priming with potassium nitrate.

	Treatments				
	0.5 mM		1 mM		Unprimed (control)
Phytochemical Constituents	6 h	12 h	6 h	12 h	
Tannins	-	-	-	-	-
Glycosides	-	-	-	-	-
Resins	+	+	+	+	+
Saponins	-	-	-	-	-
Phlobatannins	-	-	-	-	-
Flavonoids	++	+	+++	+	+
Sterols	-	-	-	-	-
Phenols	+	-	+	-	-
Carbohydrates	++	+	++	+	+
Alkaloids	+	+	+	+	-

-= Negative test (Absence of precipitation); +=Weak positive (A slight opacity/precipitation); ++=Positive test (Reactive product (Precipitation); +++=Test strongly positive

DISCUSSION

Maximum vegetative growth parameters of *Abelmoshus esculentus* obtained in seedlings primed for 6 h and at a concentration of 1 mM compared to other treatments imply that this treatment proves an advantage over other treatments. This might also be because this treatment provides adequate time for water and mineral movement in seeds necessary for metabolic processes. Meanwhile, priming for longer period until the tip of the root breaks out of the seed coat might ruin or tumble the seeds. Similar results on priming durations were observed by Farooq *et al*. (2005), Shah *et al*. (2011), and Elouaer and Hannachi (2012) which showed significant improvement in growth and yield in primed seeds of safflower and rice as against control (unprimed seeds). This result is also similar to the work of Ullah *et al*. (2002) Guzman and Olave (2006) and Mohammadi (2009) who reported that seed priming with nitrate solutions at higher concentration and lower duration enhance improved growth and yield of soybean, melon, and raya.

The significant improvement in plant growth indices of *Abelmoshus esculentus* compared to the control might be a result of fast growth in primed seedlings. It might also be due to the better development of genetic repair mechanisms in the primed seeds during priming (Nascimento, 2012). There were variations on the impact of priming on the growth indices with KNO_3 at different durations and concentrations. As one of the growth indices is enhanced by a treatment the other is inhibited. These variations in the growth indices of *Abelmoshus esculentus* among the treatments are similar to the report of Guzman and Olave (2006) on melon, Mohammadi (2009) on soybean, and Rahman *et al*. (2011) maize and chickpea seeds. Meanwhile, most of these parameters were enhanced in *Abelmoshus esculentus* primed for a shorter duration and at a higher concentration of KNO_3 (6 h primed at 1 mM). This implies that priming for a shorter duration and at a higher concentration of KNO_3 (6 h primed at 1 mM) promotes leaf initiation and expansion, and for shorter duration and at a lower concentration of KNO_3 enables proper acquisition of nutrients, water, and light for plant biomass acquisition (Tabrizian and Osareh, 2007; Pandita *et al*., 2010).

A significantly higher yield of *Abelmoshus esculentus* obtained in 6 h at 1 mM compared to other treatments implies that this treatment improves the yield quality of *Abelmoshus esculentus*. This is characterized by higher seedling growth moisture content, dry matter and pigment accumulation, and high photosynthetic rates. This agreed with the results obtained by Huang (2005) on watermelon cultivars, Hussain *et al*. (2006) on sunflower, and Abbasdokhta (2010) on wheat. This Primed-induced with KNO_3 enhancing yield components of *Abelmoshus esculentus* also correlate with the findings of Kamithi *et al*. (2016) on Chickpea, Hosseini and Koochek (2011) on sugar beet, Johnson *et al*. (2005) on chickpea, lentil, rice, and wheat.

Magnesium, calcium, potassium, zinc, sodium, and iron as well a host of phytochemicals such as resins, flavonoids, carbohydrates, phenols, phlorotannins, glycosides, and alkaloids are an important source of human diets, and their low-concentration in food can cause serious health problems (Srinivasan, 2006). From this study, it was observed that priming with inorganic salts such as KNO_3 improves the accumulation of these mineral ions and phytochemical constituents of fruits of *Abelmoshus esculentus* than unprimed. This implies that priming of seeds with KNO_3 had a positive impact on mineral ions and phytochemical accumulation of *Abelmoshus esculentus* by creating suitable osmotic conditions to improve seed imbibition and activate seed enzymes and hormones. There were variations in the impact of priming on the mineral ions and phytochemical constituents of fruits of *Abelmoshus esculentus* with KNO_3 at different durations and concentrations. These variations may be a result of the dilution of KNO_3 nutrients influencing different metabolic processes thereby enhancing and inhibiting the accumulation of these nutrients at different priming durations and concentrations. Similar results were obtained by Johnson *et al*. (2005) on the effects of micronutrient seed priming and soil fertilization on the mineral nutrition of chickpea.

CONCLUSION

Priming with inorganic salts such as KNO_3 induces faster growth and maximum crop yield of *Abelmoshus esculentus*. This was also observed for mineral and phytochemical constituents of the fruit of *Abelmoshus esculentus*. There is no threatening effect of KNO_3 from ion retention in the seed coat and embryo. Priming of seeds of *Abelmoshus esculentus* with 1 mM of KNO_3 solution for 6 h was useful in achieving maximum growth and yield and also brings about a sufficient increase in mineral and phytochemical constituents of the fruit of *Abelmoshus esculentus*. Therefore, presowing seeds enriched with inorganic nutrients like KNO_3 is agronomically beneficial. Priming for a short duration (6 h) and at high concentration is sufficient to enhance the growth process and increased yield of *Abelmoshus esculentus*, and has practical implications in the production of *Abelmoshus esculentus*.

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