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The Involvement of Gibberellins in Early Termination of Seed Dormancy and Enhanced Establishment of Seedlings of The White Guinea Yam, *Dioscorea Rotundata*

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Abstract

Nine natural and synthetic plant growth promotory hormones which included auxins –IAA, NAA, IBA and 2,4-D; gibberellins –GA_3, GA_4 and GA_7;cytokinins –BAP and kinetin; and three growth retardants – ABA, ancymidol and ethephon, were tested in two experiments for their effectiveness in breaking the dormancy in freshly harvested seeds of the white Guinea yam, *Dioscorea rotundata*. In the first, in which all the hormones were tested at 0 – 50 mgl^{-1}, dormancy was successfully terminated within one week from seed harvest as germination commenced within two days under 5.0 mgl^{-1} gibberellic acid treatments where 76.6 ± 6.9, 92. 4 ± 8.3 and 73.3 ± 6.2% germination and 0.167, 0.25 and 0.20 germination rates were obtained under GA_3, GA_4 and GA_7 respectively, relative to 4.6 ± 0.7% germination obtained from untreated seeds (control). In the second, involving gibberellins only, results of serial germination tests showed that the older the GA-treated seeds were in storage, the lower the germination rate, while the reverse was the case with maturing untreated seeds. GA was also found to promote leaf growth significantly (P=0.05), thus enhancing the assimilatory capacity of the plants. This has probably led to the increased primary productivity and consequent production of the largest tubers (the economic yield) at maturity under GA treatments. The above methods could be exploited for off-season planting that would yield reasonably-sized yam tubers at harvest, to serve both as food and propagules for the next planting season.

Keywords: Gibberellins, seed dormancy, seeding establishment, *Dioscorea rotundata.*

1.0 Introduction

Yams (*Dioscorea* species*)* are a major carbohydrate staple for millions of people in the tropical regions of the world, with the main regions of production in West Africa, South East Asia, including adjacent parts of China, Japan, Oceania and the Caribbean (Lawani and Odubanjo, 1976). West and Central Africa accounts for about 93% of the world's annual production of 38 million tonnes (FAO, 2000).

Yam is normally propagated by tubers usually cultivated for that purpose, or by setts which are cut-up ware yams. The larger the planted material, the greater the yield (Coursey, 1965; Onwueme, 1972). To expect greater harvest, therefore, a large amount of the otherwise consumable material (the tuber) is ploughed back into the ground, creating a problem of its scarcity for a greater part of the year. Infact, up to 30% of farmers' crops must be planted in the following year (IITA 1999) thus leading to a depletion of tubers that should have otherwise been consumed. Coupled with this is the great amount of labour required to produce yam. Operations such as clearing, weeding, staking, single or double harvesting, and barn preparation, all require a great amount of labour (Onwueme, 1978).

The above mentioned problems associated with propagation by tuber, have resulted to the search for alternative and more economical modes of propagation. Potentially viable alternatives include propagation by leafy nodal vine cuttings (Njoku, 1963; Akoroda and Okonmah, 1982) in which axillary buds are induced to generate whole plants that eventually yield sizeable tubers at maturity. Others include the use of tissue culture techniques in which several different explants have been employed in regenerating plantlets

eventually grow into plants that yield tubers at maturity. For example, using such explants as meristems (Ng, 1988), non-leafy nodes (Mantell *et al*, 1978), and zygotic embryos (Okezie *et al*., 2001), media containing certain basic micro and macro-element formulations such as those of Murashige and Skoog (1962) have been supplemented with low levels of auxins and cytokinins for regenerating plants that yield tubers at maturity.

The discovery that certain species of yams could flower and produce viable seeds provides an even simpler and more viable alternative for yam production. Sadik and Okereke (1975) and Sadik (1976) were able to germinate seeds of *D. rotundata* after it was realized that freshly harvested seeds from flowering populations were dormant and would require three to four months to overcome this dormancy before germination could commence. Okezie *et al*. (1986, 1993) analyzed the various components of growth of *D. rotundata* cv. Obiaoturugo propagated by seed and demonstrated the possibility of producing relatively large tubers that could either be consumed or otherwise employed as propagules for the next planting season.

The major impediment to propagation of *D. rotundata* by seed is the rather long dormancy period (10-16 weeks). Shortening this dormancy period or breaking it completely will open up a most viable and economical mode of propagation for this important food crop. A balance in the endogenous levels of hormones and other growth factors within the endosperm has been suggested in the control of seed dormancy and eventual seed germination (Wareing and Phillips, 1982; Fasidi *et al*., 2000; Ebofin *et al*., 2003). This study aims at employing a wide array of plant hormones to attempt to break seed dormancy and hasten germination and seedling establishment in *D. rotundata* cv. Obiaoturugo. Employment of the inedible seeds for propagation, rather than the edible tubers, will stem the erstwhile depletion of tubers, which should be left for consumption.

2.0 Materials and Methods

2.1 Seed Collection and Storage

Seeds of "Obiaoturugo" variety of the white Guinea yam, *Dioscorea rotundata* Poir were harvested from experimental farms of the National Root Crops Research Institute, Umudike, near Umuahia and used in this study. The experimental farms spanned an area within latitude $5^0 50'$ to $5^0 52'$ North and longitude 7^0 30' to 7^0 32' East where the plants have been observed to flower and fruit regularly for over a period of ten years.

Seeds were collected in October, 2005 and 2006 from plants raised from tubers during the 2005 and 2006 growing seasons (March-October) and used for the first and second series of experiments respectively. The seeds were extracted from the trilocular fruits and manually dewinged and sun-dried for 72 hours, packaged in thick dry brown envelopes, and stored on a mesh underlayed with calcium chloride crystals in a desiccator in the laboratory from which samples were withdrawn as desired and used for the various experiments.

2.2 Seed Germination and Hormonal Treatments

Seeds for the experiment were selected visually for their uniformity and immersed completely until submerged in $0.0 mgl^{-1}$ to $50 mgl^{-1}$ of the aqueous solutions of the test hormones for 48 hours in order to aid imbibition prior to sowing. Thereafter, they were withdrawn and surface-sterilized by immersion in one per cent sodium hypochlorite solution obtained by appropriate dilution of Clorox (a commercial bleach containing 5.25% sodium hypochlorite, NaOCl) as protection against microbial attack during germination. Immersion

in NaOCl solution was for ten minutes after which the seeds were rinsed in four changes of sterile distilled water prior to sowing in the substrate containing 0.0mgl^{-1} to 50mgl^{-1} of the plant hormones.

In the first experiment, which commenced soon after seed harvest when the seeds were still dormant, seed germination was tested in aqueous solutions of twelve natural (native) and synthetic plant growth hormones. These included four auxins: α -indoleacetic acid (IAA), -naphthaleneacetic acid (NAA), indolebutyric acid (IBA) and 2,4 –dichlorophenoxyacetic acid (2,4-D); three gibberellins –gibberellic acid 3(GA_3), gibberellic acid 4(GA_4) and gibberellic acid 7(GA_7); two cytokinins-benzylaminopurine (BAP) and kinetin; and three growth retardants - abscisic acid (ABA), ancymidol and ethephon which generates the gaseous hormone, ethylene (C_2H_4). These hormones were employed over a wide range of concentrations ranging from 0.1 to 50 mgl^{-1} while seeds treated with sterile distilled water served as control.

The substrate employed for seed germination was sterile semisolid agar (Difco-Bacto). This was made by dissolving 7.0g agar powder in about 500ml distilled water and brought to boil while stirring (with a magnetic stirrer) in a one-litre beaker on a hot plate. More distilled water was added on to the beaker to make it up to one litre resulting in 0.7% or 7mgl^{-1} agar in the final solution. The agar solution was then dispensed into 250ml Pyrex conical flasks at 100ml per flask to which appropriate concentrations of the test hormones were added. The pH of each medium was adjusted to 5.8 with drops of 1.0 normal HCl or NaOH and the flasks capped with non-absorbent cotton wool wrapped with aluminium foil prior to sterilization by autoclaving at 121^{0}C and 103 KN M^{-2} pressure for 20 minutes and then allowed to cool and solidify. Agar was preferred to other substrates as it is relatively transparent and all structures (radicle, plumule, etc.) can easily be observed right from the onset of germination rather than at above–substrate emergence as with other substrates.

Sterilized seeds were mechanically scarified by gently puncturing the testa with a sterilized needle in order to aid inhibition of the test hormones. They were then transferred into each of the conical flasks containing the media at 10 seeds per flask and five replicate flasks per treatment. During seed transfer, sterilized forceps were used to lift the surface-sterilized experimental seeds and placing them singly on the agar media. All transfers were done in a Laminar flow hood previously kept sterile by exposure to ultraviolet radiation for thirty minutes. After seed transfer, the flasks containing the seeds were placed on racks in a growth chamber (Fisons 600G3/THTL, Made in England) maintained at 27± 2^{0}C for the seeds to germinate. Germination counts were taken daily and data collected were used to calculate the maximum achievable percentage germination and germination rate (taken as the reciprocal to the number of days to 50% germination) under each hormonal treatment.

In the second experiment, stored seeds of different ages from harvest (i.e. 0.4,8 and 12 weeks from harvest) were serially germinated in media containing gibberellins only, at 5.0mgl^{-1}. Data were collected daily for 14 days for maximum achievable percentage seed germination and germination rate under each treatment. Also, the time course of seed germination as affected by seed age from the time of harvest was monitored under the various gibberellic acid treatments.

After fourteen days, when seed germination had levelled off under most of the treatments, the seedlings were then hardened prior to transfer to a greenhouse. Hardening was achieved by transplanting them into polystyrene boxes placed in a chamber fitted with intermittent misting system in which the mist cycle was initially set for a duration of 30 seconds with a 15 minute interval in order to maintain very high relative humidity. This was then lowered to one hourly interval after the first three days for a further four days. The hardened seedlings were then transferred to pots and grown for further four weeks in the greenhouse after which they were transferred to the botanical garden where they were left to grow to maturity for further 16 weeks. The plants were closely monitored for the number that withered either through chlorosis and/or necrosis and eventually died in the course of growth.

Twelve to fifteen plants were randomly selected and sampled for the dry weights of the various organs produced as affected by the gibberellic acid treatments.

2.3 Statistical Analysis

In all the experiments involving seed germination, all results were means ± standard errors of the replicate flasks containing ten seeds each. Dry weights of organs produced by the seedlings were based on destructive sampling of fifteen randomly selected plants per treatment. All the data obtained were analyzed using ANOVA, and the means compared using Duncan's Multiple Range Test.

3.0 Results

In the first experiment using freshly harvested *D. rotundata* seeds of 2005 planting, apart from abscisic acid, ancymidol, and ethephon treatments in which there was no germination at all from the freshly harvested seeds in media where they were employed at 5.0mgl^{-1} and above, all the other plant hormones supported some level of seed germination within fourteen days from sowing (Table 1). The highest percentage germination was recorded for seeds incubated in 5mgl^{-1} GA_4 where 92.4± 8.0% germination was attained, followed by 5mgl^{-1} GA_3 and GA_7 treatments under which 76.6 ± 6.9 and 73.2 ±6.2% germination were recorded respectively. Untreated seeds (control) on the other hand, attained only 4.6 ± 0.7% germination within the same period (see Table 1). In general, there was an increase in seed germination as hormonal concentrations increased from 0.1 to 5.0mgl^{-1}, beyond which higher concentrations tended to suppress this parameter in most of the treatments. Of all the hormonal treatments that supported germination, only among gibberellic acid treatments was germination rate significantly high. For example, 5.0mgl^{-1} GA_4 which supported the highest percentage germination (92.4 ± 8.0) had a germination rate of 0.25. Closely related values of 0.20 and 0.167 were also recorded in 5.0mgl^{-1} GA_7 and 5.0 mgl^{-1} GA_3 treatments respectively in which percentage germination values were comparatively high (see Table 2). Other hormonal treatments that supported any germination at all, namely 0.5 - 1.0 and 0.5 - 5.0 mgl^{-1} NAA, IBA and 2,4-D; and 0.5 t0 5.0 mgl^{-1} BAP and kinetin gave rates between 0.071 and 0.091 which were rather low relative to values recorded under gibberellic acid treatments (see Table 2).

Table 1: Effect of different plant growth hormones on the germination (%) of freshly harvested *Dioscorea rotundata* seeds.

	Hormonal Concentration (mgl^{-1})						
Treatment	0.0	0.1	0.5	1.0	5.0	10	20
IAA	4.6±0.7	3.7±0.4	8.3±2.6	6.9±1.3	8.8±1.9	5.6±1.0	4.3±0.9
NAA	4.6±0.7	5.6±0.8	11.4±2.9	10.6±1.3	14.4±2.2	8.9±1.9	6.9±0.6
IBA	4.6±0.7	5.0±0.7	13.9±3.8	17.1±1.6	19.7±1.9	10.2±2.1	5.5±0.5
2,4-D	4.6±0.7	4.9±0.6	13.0±3.6	17.9±2.1	22.3±2.8	16.8±2.0	6.8±0.8
GA_3	4.6±0.7	16.7±3.0	28.0±4.6	79.8±7.2	76.6±6.9	68.1±6.1	23.3±3.0
GA_4	4.6±0.7	26.8±4.0	43.9±4.9	70.9±6.6	92.4±8.3	86.8±9.3	29.9±2.3
GA_7	4.6±0.7	19.7±1.1	33.7±2.8	58.2±6.0	73.2±6.2	70.4±6.8	22.2±2.0
BPP	4.6±0.7	4.6±3.3	9.9±1.7	6.2±1.9	12.8±2.0	8.0±0.8	4.9±0.8
KIN	4.6±0.7	4.3±2.8	11.6±3.0	9.9±1.5	17.7±2.6	4.2±0.6	4.7±0.6
PBA	4.6±0.7	2.2±0.3	1.9±0.9	1.2±0.4	0±0	0±0	0±0
Ancymidol	4.6±0.7	1.9±0.3	1.6±0.8	1.5±0.6	0±0	0±0	0±0
Ethephon	4.6±0.7	4.1±0.9	3.6±0.9	2.2±0.4	0±0	0±0	0±0

In the second experiment, involving freshly harvested seeds of 2006 planting, the highest seed germination of 88.6 ± 9.3% was recorded for seeds treated with 5.0 mgl^{-1} GA_4, which was not significantly higher (P = 0.05) than values of 83.9 ± 6.2 and 79.7 ± 11.4% obtained under similar concentrations of GA_3 and

Table 2: Germination rate of freshly harvested *Dioscorea rotundata* seeds as affected by different plant growth hormones.

	Hormonal Concentration (mgl^{-1})							
Treatment	0.0	0.1	0.5	1.0	5.0	10	20	50
IAA	-	-	0.071	0.076	-	-	-	-
NAA	-	-	0.083	0.091	-	-	-	-
IBA	-	-	0.091	0.083	-	-	-	-
2,4-D	-	-	0.076	0.083	-	-	-	-
GA_3	-	-	0.125	0.143	0.167	0.083	-	-
GA_4	-	0.125	0.143	0.167	0.250	0.167	-	-
GA_7	-	-	0.125	0.143	0.200	0.125	-	-
BAP	-	-	0.090	0.090	0.076	-	-	-
KIN	-	-	0.090	0.100	0.083	-	-	-
ABA	-	-	-	-	-	-	-	-
Ancymidol	-	-	-	-	-	-	-	-
Ethephon	-	-	-	-	-	-	-	-

Rate: Reciprocal of the number of days to 50% germination.

GA_7 respectively. Freshly harvested, untreated seeds (control), on the other hand, could hardly germinate at this time as they could only achieve a maximum of 3.8 ± 0.2% germination within the same period (see Figure 1). As could also be clearly seen in Figure 1, the older the seeds in storage (i.e. 0, 4, 8 and 12 weeks in storage) the lower their maximum germination rate, whereas untreated seeds increased in their capacity to germinate, the longer they stayed in storage. Assessment of seed germination based on rate also showed that the highest rates (0.25-0.33) were obtained from freshly harvested seeds under the GA treatments that supported the highest percentage germination, whereas the values tended to drop with age in storage (Table 3). We can also see from Table 3 that there were no germination values recorded for untreated seeds (control) at the time of harvest (i.e 0 weeks from harvest) and 4 weeks from harvest as not up to 50 per cent germination could be achieved from such seeds at those ages. As the age of the seeds in storage increased, however, germination rate also increased among these untreated seeds. For example, 8-and 12-week old seeds had germination rates of 0.091 and 0.33 respectively (Table 3).

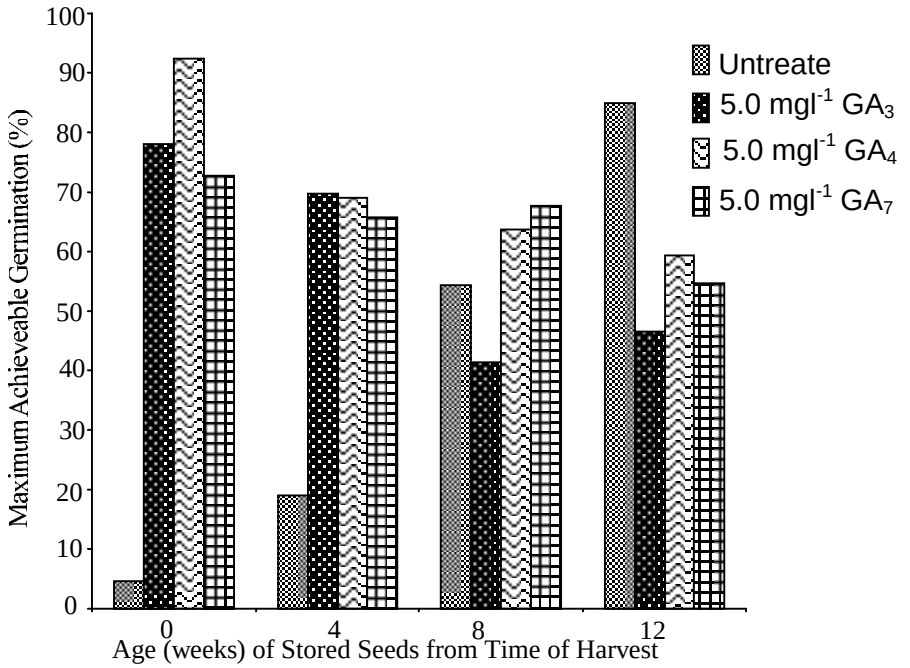


Fig.1: Maximum achievable germination (%) in 14 days with age of *Dioscorea rotundata* seeds from time of harvest as affected by the different gibberellic acid treatments.

Table 3: Germination rate of *Dioscoea rotundata* seeds as affected by age from harvest and gibberellic acid treatments.

	Germination Rate			
Gibberellic Acid Treatment	0 Week From Harvest	4 Weeks From Harvest	8 Weeks From Harvest	12 Weeks From Harvest
0.0 mg l^{-1}(control)	-	-	0.09	0.33
0.5 mg $l^{-1}GA_3$	-	-	-	-
1.0 mg $l^{-1}GA_3$	0.20	0.20	0.08	-
5.0 mg $l^{-1}GA_3$	0.33	0.25	-	-
10 mg $l^{-1}GA_3$	0.20	0.17	-	-
0.5 mg $l^{-1}GA_4$	-	0.25	0.20	-
1.0 mg $l^{-1}GA_4$	0.25	0.25	0.09	-
5.0 mg $l^{-1}GA_4$	0.33	0.33	0.08	-
10 mg $l^{-1}GA_4$	0.25	0.25	-	-
0.5 mg $l^{-1}GA_7$	-	0.17	-	0.20
1.0 mg $l^{-1}GA_7$	0.25	0.25	0.07	0.20
5.0 mg $l^{-1}GA_7$	0.25	0.17	-	-
10 mg $l^{-1}GA_7$	0.17	-	-	-

Germination rate: Reciprocal of the number of days to 50% germination.

Time course of seed germination as monitored by daily percentage germination values shows that germination started as early as the second day and levelled off after 8 days among seeds treated with 5mgl^{-1} GA irrespective of age from harvest (Figures 2A-D) . For untreated seeds, on the other hand, the older the seeds from time of harvest, the earlier the time of commencement of germination. For example, when 12 – week post-harvest seeds were soaked for 48 hours in distilled water, germination commenced after two days and levelled off by the 10th day from sowing date and had higher percentage germination values than GA –treated seeds thereafter (Figures 2A-D).

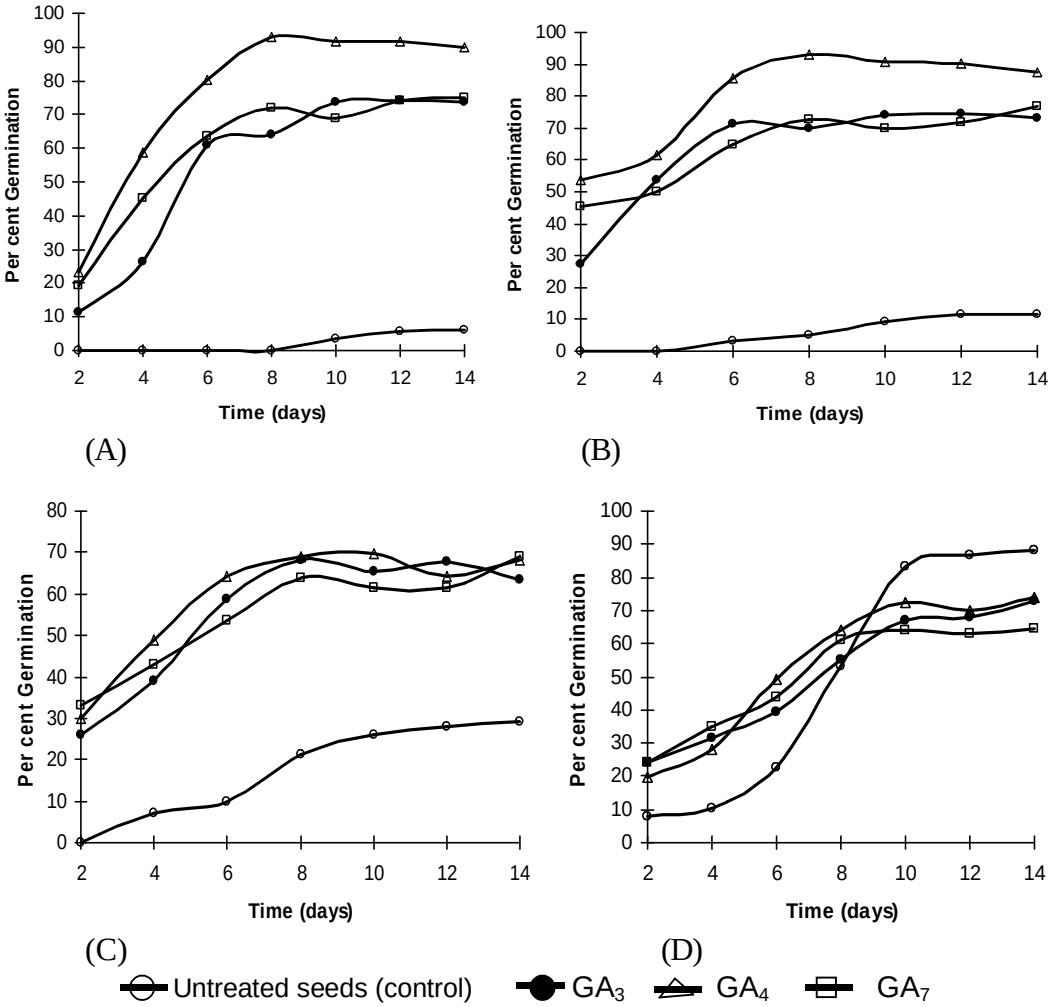
Although gibberellic acid at the levels tested, were superior in enhancing seed germination (in terms of both number and rate), and seedling establishment, significantly more (P=0.05) seedlings grew to maturity in the absence (control) rather than in the presence of gibberellins (Table 4).

Table 4: Percentage of *D. rotundata* plants surviving to maturity as affected by seed treatment with various concentrations of GA_3, GA_4 and GA_7

Treatment	Number transferred to the Field	Number surviving in the Field	Per cent survival
0.0 mg l^{-1}(control)	282	233	82.6
0.5 mg $l^{-1}GA_3$	256	215	83.9
1.0 mg $l^{-1}GA_3$	259	198	76.4
5.0 mg $l^{-1}GA_3$	273	181	66.3
10 mg $l^{-1}GA_3$	286	168	58.7
0.5 mg $l^{-1}GA_4$	269	231	85.7
1.0 mg $l^{-1}GA_4$	268	239	89.2
5.0 mg $l^{-1}GA_4$	252	188	74.6
10 mg $l^{-1}GA_4$	260	179	69.0
0.5 mg $l^{-1}GA_7$	272	238	87.5
1.0 mg $l^{-1}GA_7$	255	200	78.4
5.0 mg $l^{-1}GA_7$	273	187	68.4
10 mg $l^{-1}GA_7$	266	165	62.0

Dry weight determinations of individual plants at maturity showed that vegetative growth, as revealed by the total plant dry weight, was enhanced with increasing concentrations of GA up to 5mgl^{-1}, beyond which there was significant growth depression in plants arising from immature seeds treated with any of the gibberellins (Table 5). These enhanced total plant dry weight values from 5mgl^{-1} GA treatments were found to be as a result of the significantly higher values recorded for the leaves and tubers under these

treatments (also see Table 5). There were generally no appreciable differences in root and stem dry weights contributed to the total plant dry weights between plants raised from untreated (control) mature seeds and those raised from GA–treated seeds at the GA levels employed in this study.



Figs 2(A-D): Time course of *Dioscorea rotundata* seed germination as affected by age in storage and gibberellic acid treatments. A = Zero time from harvest; B = 4 weeks from harvest; C = 8 weeks from harvest; D = 12 weeks from harvest.

4.0 Discussion and Conclusions

It is generally recognized that levels of endogenous hormones, more than any other factors, control dormancy and seed germination in most plant species. Experiments with exogenous hormones have shown that the dormancy of many seeds can be overcome by application of gibberellins, cytokinins and ethylene (Wareing and Phillips, 1981). Results obtained in this study in which all the four auxins (at 0.5 to 10mgl^{-1}), all the three gibberellins (at 0.1 to 5.0 mgl^{-1}) and the two cytokinins (at 0.5 to 10mgl^{-1}) induced significantly more germination both in percentage and in rate relative to untreated (control) seeds are consistent with these observations. Although all the auxins and cytokinins at the levels employed were able to break dormancy in this variety of *D. rotundata*, the gibberellins were the most effective in this respect. Similar results have been reported for some other tropical plant seeds such as *Prosopis africana, Albizia lebbeck* and *Senna siamea* (Ebofin *et al*., 2003). It has been suggested that these compounds function via the activation of enzymes, mobilization of food materials leading to cell division, cell elongation and successful embryo growth and hence the germination of viable seeds (Khan, 1980; Agboola, 2003.)

Table 5: Mean dry weight of the various organs (roots, stem, leaves, and tuber) of *D. rotundata* plants at maturity as affected by seed treatment with various concentrations of GA_3, GA_4, and GA_7

Treatment	Dry Weight Roots	Dry Weight Stem	Dry Weight Leaves	Dry Weight Tuber	Total Plant Weight
0.0 mg l^{-1} (control)	467.3±34.2	613.9±47.2	2060.8±109.4	11682.6±404.9	14824.6±595.7
0.5 mg $l^{-1}GA_3$	381.7±36.8	504.6±43.7	2192.2±113.1	9923.3±397.4	13001.8±591.0
1.0 mg $l^{-1}GA_3$	372.0±39.9	555.8±60.4	2081.1±99.7	11094.0±527.6	14102.9±727.6
5.0 mg $l^{-1}GA_3$	398.8±40.3	564.0±62.1	2296.6±111.8	13552.8±573.6	16812.2±786.8
10 mg $l^{-1}GA_3$	304.7±28.6	478.3±46.9	1826.8±93.3	8973.5±521.8	11583.3±690.6
0.5 mg $l^{-1}GA_4$	412.3±49.7	558.2±61.3	2222.6±112.7	10246.0±612.7	13439.1±836.7
1.0 mg $l^{-1}GA_4$	444.7±51.0	582.1±55.5	2270.0±122.8	11967.7±650.2	15264.5±879.5
5.0 mg $l^{-1}GA_4$	473.0±39.1	627.7±56.4	2512.7±128.3	13714.1±501.9	17327.5±725.7
10 mg $l^{-1}GA_4$	382.8±44.6	512.6±48.8	2177.3±114.0	9967.6±637.7	13040.0±845.1
0.5 mg $l^{-1}GA_7$	397.9±48.7	531.3±56.9	2028.0±126.6	10108.2±577.3	13065.4±809.5
1.0 mg $l^{-1}GA_7$	402.2±50.7	537.5±63.3	1999.1±109.2	11027.0±532.5	13965.8±755.7
5.0 mg $l^{-1}GA_7$	426.5±52.4	578.3±62.6	2302.0±127.6	12824.9±460.0	16131.7±702.6
10 mg $l^{-1}GA_7$	317.7±39.6	491.7±52.2	1887.2±98.6	8236.2±412.7	10932.8±603.1

Depression of seed germination by abscisic acid, ancymidol and ethephon as found in this study, is not surprising as these are well known growth retardants. There exist a few reports, however, in which ethylene has been involved in the breakage of dormancy in certain seeds (Wareing and Phillips, 1981) but this was not the case with *D. rotundata* seeds employed in this study.

The longer the untreated (dormant) seeds stayed in storage, the greater their capacity to germinate as demonstrated by their percentage germination as well as their germination rates, suggesting an accumulation within the seeds, of the factor needed to overcome dormancy, or perhaps the disappearance of germination inhibitors with time, as suggested for some other seeds by earlier works (Khan. 1977; Bewley and Black, 1982).

Although gibberellins at the levels employed in this study were able break the dormancy of freshly harvested seeds, leading to early seed germination, more seedlings survived to maturity among those arising from untreated (control) seeds that were allowed to germinate after their natural course of dormancy (about 12 weeks). This suggests that accumulation of gibberellins (and perhaps other hormones) account for dormancy breakage in the seeds of *D. rotundata*, and that the natural period of dormancy would allow for a more efficient accumulation of these hormones. This natural period of dormancy might also make for a better balance of other accompanying growth factors that lead to breakage of dormancy and eventual seed germination.

Also evident in this study, is the enhancement of vegetative growth of the various organs which was more

pronounced in the leaf and tuber dry weights, and consequently the whole plant dry weight in plants arising from gibberellic acid-treated seeds. Similar vegetative growth enhancement by gibberellins has been reported in some food legumes (Mukaila *et al.*, 1997). Leaf growth enhancement, as found in this study, is of great physiological significance from the point of view of the leaves' photosynthetic activities accounting for the plant's primary productivity. Greater leaf growth could have led to higher net assimilation rate, (NAR) and consequently, higher dry matter accumulation in plants arising from gibberellic acid –treated seeds, relative to those raised from untreated seeds. Similar reports have also been made for Helianthus *annuus* and *Glycine max* (Seibert and Pearce, 1993) and five accessions of African yam bean, *Sphenostylis stenocarpa* (Ameh and Okezie, 2006).

Early termination of seed dormancy in this variety (Obiaoturugo) of *D. retundata* , as demonstrated in this study, has implications for off–season yam production. Dormant seeds harvested in October from plants raised by tuber during the normal growing season (March-October) could now have their dormancy broken by the application of gibberellins (especially GA_3, GA_4 and GA_7). Seedlings arising from them would then be grown for the next four to six months in order to generate sizeable tubers which can either be stored for consumption or used as supplemental progagules for the next year's planting. This way, the tubers, at least 30% of which would have been lost through the conventional planting by tuber (IITA,1999) could now be supplemented by tubers produced by plants raised from seed through gibberellin-aided termination of seed dormancy.

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