THE EFFECTS OF GIBBERELLIC ACID (GA_3), INDOLE ACETIC ACID (IAA) AND KINETIN (K) AND THEIR COMBINATIONS ON THE GROWTH AND YIELD OF ONIONS (*Allium cepa* L•)

BY

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A thesis submitted to the Postgraduate School, Ahmadu Bello University, Zaria, in partial fulfillment of the requirements of the Degree of MASTER OF SCIENCE IN AGRONOMY

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JUNE, 1988

DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented in any previous publications for a higher degree.

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ABSTRACT

Two field experiments were conducted during the wet season (June - October, 1906) and the dry season (January - May, 1907) at Samaru in the northern guinea savanna ecological zone of Nigeria to study the effect of growth regulators Gibberellic (GA_3) and Indole Acetic acid (IAA) and Kinetin (K) and their combinations at 300, GOD, 900 pprn on growth and yield of onions (Allium cepa L.).

The growth regulators were more effective in the wet season thnn in the dry season. The treatment of Gibberellic acid and kinetin at 600 ppm was the most effective combination showing significant effects on the total fresh weight and bulb fresh weight.

In the dry season, Gibberellic acid, at 600 ppm hod the highest effect on the total fresh weight, bulb and leaf fresh weight and bulb diameter.

Kinetin (K) had an inhibitory effect at (900 ppm) higher concentrations while Indole Acetic Acid (IAA) hnri a stimulatory effect at the same level. IAA had no effect at low concentrations (300 ppm).

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Chapter 1

INTRODUCTION

Onion (*Allium cepa* L.) belongs to the family Liliaceae and is a biennial plant. Among all the vegetables it ranks second to tomatoe in importance (Jourbert and Strydom, 1968). The crop is reported to have received its name from the Jews, after the name of a city called 'Onion', built by the Onias in 173 BC near the Gulf of the Suez, which had its existence for 243 years (Naqvi, 1964). Vavilov (1951) reported that onions originated from the Central Asiatic region of the world which includes North Pakistan, Afganistan and Eastern USSR.

The world total production of onion in 1976 amounted to 13 million metric tons and worth over 299 million US dollars (Anon., 1976) which has increased steadily from 11 million tonnes in 1969 to over 19 million tonnes.in 1979 (Anon., 1970b, 1980). The United States of America, China, USSR, India and Japan are the world's leading producers. Substantial commercial quantities are produced in some West African countries including Nigeria, Niger, Senegal, Ghana, Chad and Cameroun. In Nigeria, onion is particularly important in the drier parts of the Northern States; especially around the cities of Sokoto, Kano and Maiduguri (Inyang, 1966).

For better yield, the crop is grown on highly fertile

and slightly acidic and well drained soils and silt loams (Edmund et al., 1964). The crop is planted along the stream banks of Fadamas in Northern Nigeria between latitudes of 8 - 13 'N (Anon., 1981, 1985).

Onions are either cooked or eaten raw. They are important ingredients in various types of dishes; onions contain a variety of amino acids, high amount of proteins and are rich in riboflavin and calcium (Jones and Mann, 1963). Their characteristic pungent flavour is due to the presence of an aromatic volatile oil, allylpropyl sulphide which is commonly used as a flavouring agent.

There are two types of onions in relation to its colour. The first one is the white onion which is less pungent and are used mainly for consumption whereas the other type is the red type which is mainly used for medicinal purposes and is more pungent (Purseglove, 1972). The red onions are more resistant to diseases and pests and have a wide range of tolerance to the various extremes of environmental conditions thus utilized in various research trials and experiments.

Since onion has a vital role to play in agricultural production and is consumed as a very important vegetable, it is necessary to examine the physiological factors that may limit its growth and yield. Studies of the effects of growth promoters have been carried out on various crops

such as tomatoes (Roy et al., 1973), peas (Ridge, 1975) carrots (Sinha and Verma, 1974), sugarbeet (Winter, 1954) and Onions (Lipe, 1975; Olivares and Manuel, 1961). Isaac (1965), in a study on the effects of IAA, GA_3, and K at 0.1, 1.0, 10, 100 ppm on onion bulbs obtained positive effects on growth and yield. The combinations of the three growth regulators at low concentrations showed increased growth over the control. This preliminary investigation carried out in the glass-house, gave results which needed further detailed confirmation under field conditions.

The present study was, therefore, undertaken to find the effects of the growth regulators, IAA, GA_3 and K and their combinations on onion growth and yield.

Chapter 2

LITERATURE REVIEW

2.1 General Effects of Growth Regulators On Growth and Yield

A growth regulator is an organic compound (other than a nutrient) which in small amounts (< 1 mM) promotes, inhibits or qualitatively modifies growth and development (Moore, 1979). The commonly recognised plant growth regulators are auxins, gibberelins and cytokinins. The plant hormones are extremely important agents in the integration of developmental activities and they also are concerned importantly in the response of plants to the external physical environment (Moore, 1979).

2.2 General Effects of Indoleacetic Acid (IAA)

Went (1928) proposed that without auxins, there will be no growth. Almost every dynamic aspect of plant growth and development seems to be affected by auxins; in addition to cell elongation, apical dominance and abscission processes, there are effects on flower initiation and development, pollen tube growth, fruit set and fruit growth, the formation of compression wood in conifers, tubers and bulb formation and seed germination (Leopold, 1901).

By spraying auxins on water melons, summer squashes,

holly and tomatoes, seedless fruits could be produced (Wilson and Loomis, 1957). A mixture of auxins produced an appreciable effect on the size of treated potatoes (Ahmed and Sagar, 1981). Ridge (1975) found also that swellings were induced on etiolated epicotyls of peas when treated with IAA at high levels. Treatments with auxins at 100 ppm on egg plants showed maximum effect on rooting and production of fruits (Siddiqui and Khan, 1970). When plants of Datura innoxia were treated with IAA at 100 and 1000 ppm, growth and alkaloid contents increased, 100 ppm being more effective (Sinha and Verma, 1974).

2.2.1 Effect of Indoleacetic acid on growth and yield of onions

Studies involving auxins on onions have been confirmed mainly to the prevention of sprouting during storage (Tabing and Gonzalez, 1956). Acosta and York (1957) worked on the onion plants treated with maleic hydrazide and auxins. They found that auxins had an effect on storage of the onion bulbs after harvest. Oliveros and Manuel (1962) found that the effects of auxins in day lengths and temperature were found favourable for bulb formation and development of onions.

Auxins at very low concentrations were found to promote germination of onion seeds, while at higher concentrations germination was not only retarded but it was also reduced

(Pandey and Sinha, 1979). Winter (1954) found that the formation of cambia in decapitated onion and beet plants could be stimulated by the application of auxins. When onion seedlings were treated with auxins alone and auxins combined with GA and Kinetin there was a positive effect on the development and size of bulbs at a high concentration of 100 ppm (Isaac, 1905).

2.3 General Effect of Gibberellic Acid (GA_3)

Although its effects may very with various plants, GA_3 has powerful effects on stem growth and it exerts regulatory effects on plant development (Leopold, 1901). Murai et al. (1975) found that GA_3 increased plant height and prevented flower blindness.in tulips. Dormancy break and the transition to active growth were accompanied by a short rise in gibberellin activity in garlic bulbs (Rakhimbaev and Ol'shanskaya, 1971). Perennec and Crosnier (1971) soaked tubers of potato cv. Bintje and Siterna, in GA_3, and found an increase in the yield and size of tubers. In addition, bud development and stolon differentiation were promoted consequently resulting in increases in the numbers of stems and tubers, after the soaking treatment.

2.3.1 Effect of gibberellic acid on growth and yield on onions

Inhibitions of growth retardants such as N, N, diethyl 2-oxo-morpholinium (DEOMC) and chlormequat (CCC) were nullified

by GA_3 when treated on six-day old onion seedlings cv. Wolska (Knypl, 1979). Lipe (1975) noticed that GA_3 increased the number of leaves per onion plant and percentage of plants initiating multiple growing points. GA_3 increased bolting in Autumn planted Yellow Grano Onions when applied five times at 500 ppm, while a single treatment or higher concentrations of GA_3 had no effect on bolting or total seed yields but it limited seed yield per umbel (Corgan and Montano, 1975). When GA_3 was used on onion bulbs cv. Grano, at 0, 50, 150 and 450 ppm; 50 ppm treated bulbs showed an emergence of 80% floral stems and increase of flower stem height, while generally the GA_3 treated plants produced larger and more productive unbels, increasing seed yield by about 30% without affecting viability (Naamni et al., 1980). GA_3 has been reported to be more effective in increasing onion growth than other growth regulators (Olivares and Manuel, 1962).

2.4 General Effect of Kinetin (K)

Their role on plants has generally been recognised as being so widespread that it includes some aspects of growth and development. The involvement of cytokinins in tuberization and in tuber development of potatoes has been reported by Vonstaden and Dimalla (1976, 1977). Yoshida; et al. (1971) suggested that supply of kinetin on the roots of the rice crop controls yield. Palmer and Smith (1969) reported stimulation of tuber formation in potato stems.

Castro et al. (1975) found that the percentage germination by Kinetin of hot-water treated sugarcane stalks was not affected by dipping them in growth regulators but kinetin (300 ppm) and IAA (100 and 250 ppm) has a positive effect and GA_3 (500 and 200 ppm) had a negative effect on shoot growth; IAA at 250 ppm increased the dry weight of root and shoots. Kinetin when treated along with IAA and GA_3 had no effect on tomatoes habit of growth (Fricano et al., 1975). Uptake of $^{14}CO_2$ was favoured by kinetin when treated on callus of lemon stems (Hoffmon and Lenz, 1975). The involvement of several growth regulating substances such as sytokinins in tuber development has been reported by VanStaden and Dimalla (1976). Biswas and Choudhuri (1978) and Ray and Choudhuri (1981) suggested that rice yield by kinetin treatment as indicated by higher mobilization index and harvest index, might be mediated through increasedlongevity of leaves, which perhaps contributed to grain filling by enhancing the duration of photosynthetic supply to grains.

2.4.1 Effect of kinetin on growth and yield of onions

Dipping onion and tulip bulbs in mixture of kinetin along with IAA + GA_3 improved their propagation co-efficient more than a leaf spray of the same mixture (Mugge and Richter, 1975. Cytokinin activity was studied in the bulbs of garlic and onions stored for eight weeks at $4^{\circ}C$; the low temperature stimulated the accumulation of cytokinins in the

tissues (Rakhimbaev and Solomina, 1980). Effects of kinetin, along with IAA and GA_3 at concentrations of 0.1, 1.0, 10 and 100 ppm were studied on onion bulbs; there was a positive effect with kinetin at the lowest concentration, while at the highest concentration there was an inhibitory effect (Isaac, 1985). Kinetin acts as a promoter of cell division in various crops including cabbage, tomato, onions etc. (Janick, 1972).

Chapter 3

MATERIALS AND METHODS

3.1 Description of Experimental Site

The field experiment was conducted in 1906 and 1907. The 1906 trial was conducted during the rainy season, at the Horticultural Field Unit of the Institute for Agricultural Research (I.A.R.) Samaru, Zaria (11^{0} 11'N and 07^{0} 38'E and 686m above sea level) while the 1907 trial was conducted during the dry season at the Ahmadu Bello University Farm, Samaru, Zaria (11^{0} 10'N and 07^{0} 38'E and 606m above sea level).

The soil at the experimental sites were mainly silt loam and partially drained. Details of the physiochemical characteristics of the soils are shown in Table 1.

Soil samplings were done in the two fields, each at a depth of 0-15 and 15-30cms. The soil samples were analysed to determine their physio-chemical properties using the procedures by Black (1965).

After the analysis it was found that super phosphate and CAN (calcium ammonium nitrate) should be added to increase the levels of nitrogen and phosphorus in the soil for the growth of the onion plants.

Table 1: Physico - Chemical Properties of Soil of the Horticultural Field Unit, IAR and the ABU Farm Samaru during the Wet and Dry Season.

Soil Characteristics	Hort.Field Unit		A.B.U. Farm	
	0-15cm	15-30cm	0-15cm	15-30cm
Per cent Clay	8.0	12.0	4.0	12.0
Per cent Silt	53.0	47.0	53.0	40.0
Per cent sand	42.0	41.0	41.0	48.0
Class	Silt loam	Loam	Silt loam	Loam
pH in H_2O	5.25	5.3	5.0	5.05
pH in $CaCl_2$	5.0	5.1	5.35	5.55
Organic Carbon (%)	0.7	0.6	0.95	0.95
Total nitrogen (%)	0.06	0.7	0.08	0.08
Available phosphorus (ppm)	6.09	7.41	5.09	5.96
Total phosphorus (ppm)	108.47	124.72	91.39	97.22
C.E.C. (Meg/100g soil)	4.95	4.0	7.40	8.95
% Base Saturation	49.20	52.55	55.91	44.06
Exchangeable Bases (Meg/100g soil)				
Ca	2.39	1.65	2.31	2.20
Mg	0.40	0.40	1.22	1.19
K	0.25	0.25	0.44	0.43
Na	0.07	0.08	0.80	0.77

3.2 Treatments, Experimental Design and Plot Size

Both experiments were laid out in a randomized complete block design with factorial arrangements and had the following treatments:- three growth regulators (IAA, GA_3, K) and three concentrations (300, 600 and 900 ppm) of each growth regulator.

There was a control treatment without any growth regulator. A total of 22 treatments replicated three times i.e. total plot number was (21 + 1)3 = 66 treatment plots. The plot sizes were $3.75m^2$ and $2.25m^2$ for the 1986 wet season and 1987 dry season, respectively.

3.3 Field Operations

3.3.1 Land preparation and fertilizer application

The fields were ploughed and harrowed. Sunken beds were made during the dry season while beds were raised during the wet season for adequate water retention and flow, respectively. Before the preparation of the beds, the experimental site received 11kg of well-rotten farmyard manure per square meter which was thoroughly mixed with the top soil. The experimental site also received a basal application of 45kg P/ha^{-1} as single superphosphate (10% P_2O_5).

Nitrogen was applied at the rate of 65kg N/ha^{-1} as calcium ammonium nitrate (26% N) in two split doses. The first

dose was applied two weeks after transplanting and the second was applied four weeks later.

3.3.2 Nursery practices

In the nursery, the seeds of Red Kano cultivar, were sown into trays containing sterilized soil on 16th May, 1986 for the wet season trial and on the 6th November, 1986, for the dry season trial. Seeds were drilled in rows 10 - 15cms apart and 1½cms deep.

The seed trays were mulched to prevent washing during the rains and to decrease evaporation from the soil during the dry season.

3.3.3 Preparation of the growth regulator solutions

Five hundred miligrams of the IAA and GA_3 powder was taken and dissolved into 20mls of sodium hydroxide (0.1N) solution, while the same amount of kinetin was taken and dissolved into hydrochloric acid (0.1N). The solutions were taken made up to 500ml separately with distilled water. These stock solution were then diluted as necessary in order to obtain the different required concentrations.

3.3.4 Seedling transplanting

After six weeks of growth, the seedlings were carefully uprooted and washed. They were then dipped into the already prepared growth regulator solutions for five minutes before

transplanting into the field, at the spacing of 10 by 20cm per plot.

3.3.5 Crop protection

Hoe weeding was done at regular intervals since onions compete very poorly with weeds. Special hand hoes were used in order not to compact the soil unduly.

Onion twister disease was treated during the wet season with Benlate and Dithane M45 applied at the rate of 2.5kg ai/ha^{-1}. Plants were sprayed at weekly intervals, although complete control was not achieved. During the dry season the crops were free of the twister disease, therefore, there was no need for application of any fungicides.

3.3.6 Harvesting

When 50% of the tops in the field had fallen over, the onions were harvested. The onions were carefully pulled by hand ensuring that the roots were not completely destroyed while uprooting, for sampling.

3.4 Data Collection and Observations

3.4.1 Sampling

Five plants were randomly selected from each plot for sampling. During sampling at an interval of four weeks, various parameters were recorded, which included fresh weights of bulbs, leaves, roots, dry weights of bulbs leaves, roots;

total fresh and dry weights; leaf area, number of leaves, bulb diameter and heights of the plants.

During sampling, the bolting percentage were noted and recorded. There were also certain double bulbs obtained which were recorded. The meteorological data given in Appendix 2 and 3 was used to determine the period of trial, in both the seasons.

3.4.2 Analysis of data

An analysis of variance was done to test the treatment effects for significance using the 'F' test as described by Snedecor and Cocharan (1967). The standard error and Duncan's Multiple range test was also determined (Duncan, 1955).

Chapter 4

RESULTS

4.1 Effect of Growth Regulators and their Combinations on the Growth of Onions During the Wet Seasons (June - October 1986)

4.1.1 Total fresh weight

The growth regulators had significant effect on the total fresh weight per plant at 8 weeks after transplanting and 12 WAT only (Table 2).

The highest weight was produced at 8 WAT by the combination of GA_3 + IAA at 600 ppm. However, this was not significantly different from the control. When the other treatments were compared with control, there was no significant difference too, this included also, the least weight obtained with the application of IAA + K at 600 ppm.

At 12 WAT, the largest weight obtained was under the influence of GA_3 + K at 300 ppm, which was significantly higher than the values obtained from treatments 22 (control), 16, 2, 5, 17, 15, 12, 20 and 21. The least weight recorded was produced by GA_3 + IAA + K at 600 ppm, but this was not significantly different from the control (Table 2).

4.1.2 Bulb fresh weight

The growth regulators had no influence on the bulb

Table 2: Total fresh weight (g) per Plant of Onion as influenced by the Growth Regulators and their Combinations during the Wet Season at Samaru in 1986.

TREATMENTS	4 WAT	8 WAT	12 WAT	16 WAT
1.GA-300	49.3	277.0 e-g	346.0 a-b*	114.6
2.GA-600	57.3	343.0b-g	335.5 b-h	164.2
3.GA-900	65.9	510.0a-g	410.6 ab	120.0
4.IAA-300	92.7	557.0 a-e	340.6 a-h	124.4
5.IAA-600	53.0	440.0 a-g	305.1 b-h	124.3
6.IAA-900	60.5	466.0 a-g	399.0 a-f	113.0
7.K-300	60.4	374.0 a-g	413.4 a-c	95.2
0.K-600	63.2	417 a-g	344.1 a-h	120.4
9.K-900	54.0	572.0 a-d	244.0 gh	120.3
10.GA+IAA-300	67.7	535.0 a-g	365.0 a-h	141.4
11.GA+IAA-600	60.5	654.0a	399.9 a-e	144.3
12.GA+IAA-900	55.0	423.0 a-g	249.1 d-h	125.2
13.GA+K-300	74.5	601.0ab	495.3 a	135.0
14.GA+K-600	60.3	523.0 a-g	401.4 a-d	121.0
15.GA+K-900	41.7	322.0 b-g	262.0 d-h	100.3
16.IAA+K-300	53.5	555.0 a-f	337.5 b-h	111.7
17.IAA+K-600	35.0	251.0 g	272.6 b-h	100.5
10.IAA+K-900	40.0	312.0 b-g	302.6 a-h	109.3
19.GA+IAA+K-300	72.0	579.0 a-c	340.7 a-h	116.3
20.GA+IAA+K-600	90.0	340.0 b-g	246.0 gh	114.1
21.GA+IAA+K-900	47.7	439.0 a-g	229.0 h	136.7
22. Control	01.5	430.0 a-g	330.9 b-h	125.0
SED	17.9	125.3	66.07	130.9
Significance ('F' test)	NS	**	**	NS

Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

Means followed by two letters connected with a hyphen are included in all groupings between the two letters in the alphabet.

WAT - Weeks after transplanting.
** - Significant at 1% level
NS - Not significant.

fresh weight at 4, 8, and 16 WAT (Table 3). Differences between the various treatments were however, significant at 12 WAT.

At this sampling, GA_3 + K at 300 ppm gave the highest bulb fresh weight. The least weight produced was with IAA + K at 300 ppm. This treatment was, however, not different from the control. Although when comparing the control with treatments 3, 6, 7, 11, 13, 14 and 10; there was a significant different produced with the least weight.

4.1.3 Leaf fresh weight

The application of the three growth regulators singly or in various combinations had no significant effect on the fresh weight of the leaf per plant at any of the sampling periods (Table 4).

4.1.4 Leaf length, number of leaves and bulb diameter

The above parameters did not show any significant difference under the influence of the growth regulators at any of the concentrations used (Tables 5, 6 and 7).

4.1.5 Bulb dry weight

Onion bulb dry weight was significantly effected by the growth regulators at 8 and 12 WAT only (Table 8).

At 8 WAT, GA_3 + K at 300 ppm, gave the largest bulb dry

Table 3: Bulb Fresh Weight (g) per Plant of Onion as influenced by the Growth Regulators and their Combinations during the wet Season at Samaru in 1986.

TREATMENTS	4 WAT	8 WAT	12 WAT	16 WAT
1.GA-300	8.05	269.0	312.0 a-g*	272.30
2.GA-600	9.05	175.0	292.0 a-g	303.70
3.GA-900	10.40	291.0	393.0 ab	325.60
4.IAA-300	15.95	359.0	299.0 a-g	416.60
5.IAA-600	7.65	253.0	253.0 b-g	305.60
6.IAA-900	12.17	355.0	351.0 a-g	339.60
7.K-300	9.70	190.0	370.0 a-e	346.00
8.K-600	11.47	227.0	371.0 a-d	352.30
9.K-900	8.81	202.0	215.0 fg	292.50
10.GA+IAA-300	11.42	330.0	344.0 a-g	391.20
11.GA+IAA-600	11.30	276.0	373.0 a-c	373.40
12.GA+IAA-900	9.69	211.0	226.0 c-g	353.90
13.GA+K-300	8.46	322.0	441.0 a	412.60
14.GA+K-600	10.20	296.0	360.0 a-f	314.60
15.GA+K-900	9.63	136.0	220.0 c-g	310.40
16.IAA+K-300	8.31	190.0	190.0 g	359.90
17.IAA+K-600	5.90	117.0	243.0 a-g	335.70
18.IAA+K-900	5.71	162.0	350.9 a-g	323.60
19.GA+IAA+K-300	12.64	400.0	323.0 b-g	361.40
20.GA+IAA+K-600	13.63	194.0	239.0 b-g	469.20
21.GA+IAA+K-90	8.19	260.0	213.0 fg	300.20
22. Control	15.25	259.0	307.0 a-g	353.90
SED	3.15	80.1	66.4	60.36
Significance ('F' test)	NS	NS	**	NS

* Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

Means followed by two letter connected with a hyphen are included in all groupings between the two letters in the alphabet.

WAT - Weeks after transplanting.

** - Significant at 1% level.

NS - Not significant

Table 4: Leaf Fresh Weight (g) per Plant of Onion as influenced by the growth Regulators and three combinations during the wet season at Samaru in 1906.

TREATMENTS	4 WAT	8 WAT	12 WAT
1.GA-300	37.3	149.0	22.9
2.GA-600	43.0	199.0	26.1
3.GA-900	51.0	197.0	14.7
4.IAA-300	72.5	194.0	22.4
5.IAA-600	41.7	190.0	32.1
6.IAA-900	53.2	169.0	34.0
7.K-300	49.9	167.0	24.6
8.K-600	47.9	163.0	21.2
9.K-900	43.1	249.0	16.9
10.GA+IAA-300	52.2	299.0	12.0
11.GA+IAA-600	54.0	411.0	14.9
12.GA+IAA-900	42.0	197.0	16.1
13.GA+K-300	57.9	250.0	20.7
14.GA+K-600	47.14	210.0	21.5
15.GA+K-900	32.0	140.0	23.4
16.IAA+K-300	41.1	220.0	129.7
17.IAA+K-600	27.05	121.0	21.3
10.IAA+K-900	47.05	137.0	22.2
19.GA+IAA+K-300	55.0	109.0	15.3
20.GA+IAA+K-600	75.9	137.0	12.6
21.GA+IAA+K-900	36.2	151.0	10.0
22. CONTROL	32.7	153.0	23.2
SED	15.6	72.0	32.59
Significance ('F'test)	NS	NS	NS

WAT - Weeks after transplanting.

NS - Not significant.

Table 5: Leaf length (cm) per plant of Onion as influenced by the growth Regulators and their Combinations during the wet season at Samaru in 1986.

TREATMENTS	4 WAT	8 WAT
1.GA-300	35.07	31.42
2.GA-600	30.57	44.53
3.GA-900	41.47	40.09
4.IAA-300	44.93	45.6
5.IAA-600	36.0	49.7
6.IAA-900	41.07	43.53
7.K-300	30.2	46.5
8.K-600	39.53	43.3
9.K-900	40.13	49.4
10.GA+IAA-300	37.67	52.2
11.GA+IAA-600	40.07	43.27
12.GA+IAA-900	30.4	40.29
13.GA+K-300	42.93	47.97
14.GA+K-600	37.53	45.0
15.GA+K-900	36.27	45.69
16.IAA+K-300	38.33	45.67
17.IAA+K-600	35.09	47.79
18.IAA+K-900	39.2	44.72
19.GA+IAA+K-300	40.47	43.17
20.GA+IAA+K-600	37.53	43.3
21.GA+IAA+K-900	30.53	50.99
22. CONTROL	41.6	48.99
SED	3.935	5.96
Significance ('F' test)	NS	NS

WAT - Weeks after transplanting.

NS - Not significant.

Table 6: Effect of Growth Regulators and their Combinations on the number of leaves per plant during the Wet Season at Samaru in 1986.

TREATMENTS	4 WAT	8 WAT	12 WAT
1.GA-300	5.33	9.0	13.0
2.GA-600	5.67	10.2	11.67
3.GA-900	5.33	10.67	12.33
4.IAA-300	6.0	12.3	11.0
5.IAA-600	5.67	12.33	11.33
6.IAA-900	6.0	13.0	12.0
7.K-300	5.6	10.0	12.67
8.K-600	6.0	10.67	12.33
9.K-900	6.0	11.07	11.0
10.GA+IAA-300	6.0	11.67	11.33
11.GA+IAA-600	6.0	14.67	10.33
12.GA+IAA-900	5.67	11.67	12.0
13.GA+K-300	5.10	15.0	13.0
14.GA+K-600	5.57	11.33	11.67
15.GA+K-900	5.57	10.0	11.67
16.IAA+K-300	5.33	13.67	11.67
17.IAA+K-600	5.33	11.33	12.0
18.IAA+K-900	5.33	12.33	12.0
19.GA+IAA+K-300	6.33	11.0	11.0
20.GA+IAA+K-600	6.33	13.67	11.33
21.GA+IAA+K-900	6.33	15.67	12.0
22. CONTROL	5.33	9.67	10.33
SED	1.76	2.40	1.43
Significance ('F' test)	NS	NS	NS

WAT - Weeks after transplanting.

NS - Not significant.

Table 7: Effect of Growth Regulators and their Combinations on the Bulb Diameter of each Bulb per plant of Onions during the Wet Season at Samaru in 1986.

TREATMENTS	4 WAT	8 WAT	12 WAT	16 WAT
1.GA-300	0.996	3.62	4.07	5.37
2.GA-600	1.166	4.21	4.09	5.72
3.GA-900	1.114	4.09	5.09	5.20
4.IAA-300	1.33	5.4	5.43	5.92
5.IAA-600	0.93	5.35	5.16	5.13
6.IAA-900	1.106	4.55	5.67	5.44
7.K-300	1.16	4.32	6.11	5.02
8.K-600	1.10	5.16	5.04	5.53
9.K-900	1.00	4.94	4.96	5.65
10.GA+IAA-300	1.116	5.37	5.01	5.09
11.GA+IAA-600	1.09	4.04	5.93	5.79
12.GA+IAA-900	1.006	4.67	5.10	5.64
13.GA+K-300	1.233	5.10	6.56	5.10
14.GA+K-600	1.096	5.16	5.25	5.9
15.GA+K-900	0.070	4.20	4.10	6.03
16.IAA+K-300	1.04	5.10	6.17	5.65
17.IAA+K-600	1.006	4.04	5.93	5.69
18.IAA+K-900	1.030	4.32	5.92	5.67
19.GA+IAA+K-300	1.360	6.02	5.30	5.63
20.GA+IAA+K-600	1.44	5.45	5.77	5.65
21.GA+IAA+K-900	1.196	6.01	5.75	6.67
22. CONTROL	1.206	5.24	5.15	6.40
SED	1.55	0.001	0.701	1.360
Significance ('F' test)	NS	NS	NS	NS

WAT - Weeks after transplanting.

NS - Not significant.

Table 8: Bulb Dry Weight (g) per plant as influenced by the growth Regulators and their Combinations of Onions during Wet Season at Samaru in 1986.

TREATMENTS	4 WAT	8 WAT	12 WAT	16 WAT
1.GA-300	0.78	56.1 d-b*	20.92 a-f	23.04
2.GA-600	1.43	50.5 c-b	19.62 d-1	31.3
3.GA-900	0.079	140.4 a-e	23.8 a-i	20.4
4.IAA-300	1.769	133.7 a-f	29.4 a-e	29.4
5.IAA-600	0.96	03.5 a-h	17.6 c-i	21.3
6.IAA-900	1.64	90.0 a-b	20.43 a-h	20.3
7.K-300	0.029	44.4 f-h	26.41 a-i	29.5
8.K-600	2.79	08.2 a-h	21.00 b-i	26.3
9.K-900	0.946	105.0 a-h	14.7 f-i	34.3
10.GA+IAA-300	1.106	126.5 a-g	29.6 a-c	20.7
11.GA+IAA-600	0.966	00.9 a-h	34.0 ab	29.0
12.GA+IAA-900	0.790	76.3 c-h	16.9 c-i	20.3
13.GA+K-300	1.096	102.2 a	36.3 a	30.1
14.GA+K-600	0.005	52.5 f-h	27.0 a-i	26.3
15.GA+K-900	0.430	25.9 g	10.7 c-i	25.6
16.IAA+K-300	0.746	140.6 a-d	24.0 a-i	34.6
17.IAA+K-600	0.533	157.3 a-c	10.5 c-i	30-6
10.IAA+K-900	0.40	41.1 f-h	29.4 a-e	30.1
19.GA+IAA+K-300	1.660	172.0 ab	20.92 a-g	30.51
20.GA+IAA+K-600	1.640	64.1 c-h	20.4 b-i	37.4
21.GA+IAA+K-900	0.67	96.9 a-h	13.63 i	24.35
22. CONTROL	1.526	22.2 h	22.2 a-i	5.06
SED	0.014	41.14	6.22	
Significance ('F' test)	NS	**	**	NS

* Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

Means followed by two letters connected with a hyphen are included in all groupings between the two letters in the alphabet.

WAT - Weeks after transplanting.
** - Significant at 1% level.
NS - Not significant.

weight which was significantly higher than the control. The control gave the lowest weight, followed by GA_3 + K at 900 ppm. Bulb dry weight of treatments 3, 4, 13, 16, 17 and 19 were significantly higher than that of the control.

At 12 WAT, the highest weight obtained was also due to GA_3 + K at 300 ppm but when compared with the control, there was no significant difference. The least weight was due to GA_3 + K at 900 ppm, which, also did not differ from the control, along with all the other treatment (Table 8).

4.1.6 Leaf dry weight and root dry weight

The data recorded in Table 9 and 10, showed no significant effect of the growth regulators on leaf dry weight and root dry weight per plant at all the sampling periods.

4.2 Effect of Growth Regulators and their Combinations on the Growth of Onions during the Dry Season (January-May, 1987)

4.2.1 Total fresh weight

At 4 WAT, total fresh weight per plant was significantly ($p = 0.01$) influenced by the growth regulators while differences between the various treatments at subsequent samplings were not significant (Table 11).

The largest total fresh weight was obtained by the application of GA_3 at 600 ppm while GA_3 + IAA + K at 900 ppm

Table 9: Leaf Dry Weight (g) per plant as influenced by the growth regulators and their Combinations of Onion during the Wet Season at Samaru in 1986.

TREATMENTS	4 WAT	8 WAT	12 WAT
1.GA-300	2.90	41.2	3.41
2.GA-600	2.06	19.4	5.60
3.GA-900	3.90	15.4	3.44
4.IAA-300	4.62	15.9	5.75
5.IAA-600	2.79	7.4	4.13
6.IAA-900	3.1	8.1	4.45
7.K-300	3.99	11.3	6.10
8.K-600	3.96	11.4	4.22
9.K-900	3.15	22.3	3.77
10.GA+IAA-300	3.99	20.1	2.51
11.GA+IAA-600	3.66	14.4	4.02
12.GA+IAA-900	3.01	23.6	2.52
13.GA+K-300	4.00	20.5	4.29
14.GA+K-600	1.92	22.0	4.47
15.GA+K-900	3.02	13.1	4.21
16.IAA+K-300	3.26	19.3	3.63
17.IAA+K-600	2.13	32.0	2.83
18.IAA+K-900	2.59	13.1	5.01
19.GA+IAA+K-300	3.93	13.4	3.47
20.GA+IAA+K-600	4.04	16.9	2.49
21.GA+IAA+K-900	2.25	19.4	2.71
22. CONTROL	4.66	19.5	3.05
SED	1.12	11.3	1.55
Significance ('F' test)	NS	NS	NS

WAT - Weeks after transplanting

NS - Not significant.

Table 10: Root dry weight (g) per Plant of Onions as influenced by the growth regulators and their Combinations during the Wet Season at Samaru in 1986.

TREATMENTS	4 WAT	8 WAT	12 WAT
1.GA-300	0.23	1.30	0.14
2.GA-600	0.54	0.52	0.04
3.GA-900	0.37	3.01	0.19
4.IAA-300	0.34	1.90	0.07
5.IAA-600	0.29	2.44	0.17
6.IAA-900	0.40	1.59	0.06
7.K-300	0.20	0.90	0.06
8.K-600	0.47	1.71	0.11
9.K-900	0.29	2.07	0.45
10.GA+IAA-300	0.69	4.23	0.10
11.GA+IAA-600	0.23	1.91	0.10
12.GA+IAA-900	0.26	1.32	0.36
13.GA+K-300	0.43	2.64	0.10
14.GA+K-600	0.23	1.46	0.26
15.GA+K-900	0.29	0.69	0.09
16.IAA+K-300	0.30	2.11	0.09
17.IAA+K-600	0.24	5.31	0.66
18.IAA+K-900	0.26	1.55	0.63
19.GA+IAA+K-300	0.40	2.50	0.37
20.GA+IAA+K-600	0.40	1.30	0.10
21.GA+IAA+K-900	0.51	2.22	2.04
22. CONTROL	0.39	1.51	0.30
SED	0.10	1.41	0.74
Significance ('F' test)	NS	NS	NS

WAT - Weeks after transplanting.

NS - Not significant.

Table 11: Effects of the Growth Regulators and their Combinations on the total fresh weight (g) per plant of Onions during the Dry Season at Samaru in 1987.

TREATMENTS	4 WAT	8 WAT	12 WAT	16 WAT
1.GA-300	51.0 a-f*	271.2	359.0	366.0
2.GA-600	62.7 a	291.6	403.0	494.0
3.GA-900	45.0 a-f	280.1	454.0	599.0
4.IAA-300	54.5 a-d	232.4	421.0	733.0
5.IAA-600	54.5 a-c	296.5	320.0	563.0
6.IAA-900	53.1 a-f	255.1	216.0	753.0
7.K-300	45.5 a-f	315.0	354.0	334.0
8.K-600	55.2 ab	255.3	404.0	369.0
9.K-900	40.3 a-f	300.5	493.0	601.0
10.GA+IAA-300	39.3 b-f	220.0	446.0	606.0
11.GA+IAA-600	35.5 b-f	250.2	412.0	435.0
12.GA+IAA-900	33.1 b-f	373.2	242.0	722.0
13.GA+K-300	44.9 a-f	211.5	500.0	606.0
14.GA+K-600	40.0 a-f	266.9	477.0	431.0
15.GA+K-900	36.9 b-f	226.1	400.0	440.0
16.IAA+K-300	34.7 b-f	300.6	484.0	731.0
17.IAA+K-600	32.7 b-f	250.2	404.0	544.0
18.IAA+K-900	31.1 b-f	245.5	462.0	475.0
19.GA+IAA+K-300	32.7 b-f	235.6	491.0	463.0
20.GA+IAA+K-600	33.0 b-f	205.9	430.0	463.0
21.GA+IAA+K-900	28.0 f	273.9	339.0	650.0
22. CONTROL	53.4 a-e	276.4	552.0	810.0
SED	18.3	59.47	156.7	239.0
Significance ('F' test)	**	NS	NS	NS

*Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

Means followed by two letters connected with a hyphen are included in all groupings between the two letters in the alphabet.

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NS - Not significant

** - Significant at 1% level.

gave the least weight. When the control was compared with the largest fresh weight and all the other treatments except the lowest weight, there was no significant difference produced.

4.2.2 Bulb fresh weight

Application of the growth regulators had significant ($p = 0.01$) effect on bulb fresh weight per plant only at 4 WAT (Table 12).

The growth regulator IAA at 900 ppm produced the largest bulb fresh weight at 4 WAT but this was not significantly different from the control. The least weight produduced by the combination of IAA + K at 300 ppm was, however, different from the control. The other treatments which were significantly different when compared to the control included 17, 18, 20 and 21.

4.2.3 Leaf fresh weight

At 0 and 12 WAT, the leaf fresh weight was not influenced by the growth regulators (Table 13). At 4 WAT the fresh weight of the leaves of the various treatments were significantly ($p = 0.01$) different.

GA_3 at 600 ppm produced the largest leaf fresh weight but this was not different from the control. However, when the control was compared with the lowest weight obtained

Table 12: Effects of the Growth Regulators and their Combinations on the Bulb fresh weight (g) per Plant of Onions during the dry season at Samaru in 1987.

TREATMENTS	4 WAT	8 WAT	12 WAT	16 WAT
1.GA-300	11.30 a-g*	113.2	254.0	205.0
2.GA-600	10.54 a-g	125.2	333.0	410.0
3.GA-900	11.67 a-g	106.8	330.0	497.0
4.IAA-300	13.36 a-f	87.4	336.0*	401.0
5.IAA-600	14.10 ab	113.3	321.0	476.0
6.IAA-900	14.44 a	121.6	156.0	409.0
7.K-300	11.39 a-g	120.9	250.0	312.0
8.K-600	13.81 a-d	93.9	337.0	296.0
9.K-900	8.22 b-g	113.7	368.0	552.0
10.GA+IAA-300	10.64 a-g	90.3	297.0	535.0
11.GA+IAA-600	8.72 a-g	129.0	290.0	380.0
12.GA+IAA-900	11.62 a-g	154.0	150.0	627.0
13.GA+K-300	9.23 a-g	76.2	367.0	522.0
14.GA+K-600	13.96 a-c	127.1	350.0	304.0
15.GA+K-900	9.05 a-g	106.5	304.0	298.0
16.IAA+K-300	6.23 g	104.7	302.0	667.0
17.IAA+K-600	7.65 e-g	116.1	276.0	446.0
18.IAA+K-900	7.19 e-g	90.5	337.0	405.0
19.GA+IAA+K-300	8.59 a-g	102.0	368.0	424.0
20.GA+IAA+K-600	7.26 e-g	88.5	336.0	304.0
21.GA+IAA+K-900	6.76 g	120.9	252.0	590.0
22. CONTROL	13.62 a-e	131.5	440.0	802.0
SED	2.623	31.14	127.5	211.5
Significance ('F' test)	**	NS	NS	NS

*Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

Means followed by two letters connected with a hyphen are included in all groupings between the two letters in the alphabet.

WAT - Weeks after transplanting

NS - Not significant.

** - Significant at 1% level.

Table 13: Effects of the Growth Regulators and their Combinations on the Leaf fresh weight (g) per plant of Onions during the Dry Season at Samaru in 1987.

TREATMENTS	4 WAT	8 WAT	12 WAT
1.GA-300	44.7 a-d*	156.0	57.3
2.GA-600	47.1 a	165.0	47.1
3.GA-900	34.3 a-d	153.0	47.0
4.IAA-300	47.0 ab	145.0	40.0
5.IAA-600	44.1 a-e	150.0	26.7
6.IAA-900	43.2 a-f	104.0	21.1
7.K-300	37.2 a-h	150.0	35.5
8.K-600	46.0 a-c	160.0	19.0
9.K-900	26.0 c-h	211.0	44.1
10.GA+IAA-300	33.1 a-h	123.0	29.7
11.GA+IAA-600	27.9 a-h	129.0	30.1
12.GA+IAA-900	29.9 b-h	206.0	21.3
13.GA+K-300	21.5 gh	135.0	27.6
14.GA+K-600	30.7 a-h	139.0	24.6
15.GA+K-900	20.0 a-h	140.0	61.4
16.IAA+K-300	29.6 a-h	185.0	20.3
17.IAA+K-600	23.1 a-h	144.0	31.1
18.IAA+K-900	24.7 e-h	155.0	20.1
19.GA+IAA+K-300	24.5 e-h	453.0	30.6
20.GA+IAA+K-600	25.7 d-h	132.0	39.9
21.GA+IAA+K-900	22.0 gh	155.0	34.4
22. CONTROL	43.1 a-b	145.0	34.1
SED	0.67	106.6	16.05
Significance ('F' test)	**	NS	NS

*Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

Means followed by two letter connected with a hyphen are included in all groupings between the two letters in the alphabet.

WAT - Weeks after transplanting.

NS - Not significant.

** - Significant at 1% level.

(GA_3 + K at 300 ppm) and the treatment due to GA_3 + IAA + K at 900 ppm there was a significant difference.

4.2.4 Leaf length and number of leaves

Application of the growth regulators had no significant effect on the leaf length and leaf number (Tables 14 and 15).

4.2.5 Bulb diameter

The growth regulators had significant ($p = 0.01$) effect on the bulb diameter at 4 WAT only (Table 16).

The least weight was obtained from the treatment GA_3 + IAA + K at 900 ppm, followed by the effect of GA_3 + K at 300 ppm. There was a significant difference compared with the control. However, when the control was compared with the treatment GA at 600 ppm which produced the maximum bulb diameter there was no significant difference obtained statistically.

4.2.6 Leaf area

The above parameter was not influenced by the growth regulators at any of the sampling periods (Table 17).

4.2.7 Bulb dry weight

Significant effect of the growth regulators on bulb dry weight was observed at 4 WAT only (Table 18).

Table 14: Effects of the Growth Regulators and their Combinations on the leaf length (cm) per plant of Onions during the Dry Season at Samaru in 1987.

TREATMENTS	4 WAT	8 WAT	12 WAT
1.GA-300	46.43	44.5	52.7
2.GA-600	44.77	54.1	56.0
3.GA-900	43.77	37.97	52.0
4.IAA-300	44.80	47.5	50.3
5.IAA-600	49.03	44.27	53.0
6.IAA-900	46.73	43.63	48.3
7.K-300	43.03	47.97	55.7
8.K-600	43.9	45.03	45.0
9.k-900	30.7	50.3	54.0
10.GA+IAA-300	40.7	47.07	59.0
11.GA+IAA-600	42.23	45.27	53.3
12.GA+IAA-900	41.13	44.07	53.0
13.GA+K-300	37.40	45.87	50.3
14.GA+K-600	47.07	47.1	62.7
15.GA+K-900	43.07	47.3	43.1
16.IAA+K-300	39.67	45.97	47.7
17.IAA+K-600	36.27	47.53	59.0
18.IAA+K-900	43.43	46.7	64.7
19.GA+IAA+K-300	44.03	40.17	55.3
20.GA+IAA+K600	44.7	46.97	55.7
21.GA+IAA+K-900	34.77	45.03	52.3
22. CONTROL	46.03	36.63	55.7
SED	4.095	4.054	0.66
Significance ('F' test)	NS	NS	NS

WAT - Weeks after transplanting.
NS - Not significant.

Table 15: Number of leaves per plant of Onions as Influenced by the Growth Regulators and their Combinations during Dry Season at Samaru in 1987.

TREATMENTS	4 WAT	8 WAT	12 WAT
1.GA-300	8.67	11.67	12.0
2.GA-600	9.67	14.33	12.33
3.GA-900	10.67	12.67	16.67
4.IAA-300	11.33	11.0	13.67
5.IAA-600	9.67	10.93	11.67
6.IAA-900	12.0	10.67	15.0
7.K-300	11.0	14.67	16.0
8.K-600	14.33	17.33	13.0
9.K-900	11.0	10.67	16.33
10.GA+IAA-300	12.33	14.0	13.0
11.GA+IAA-600	12.67	11.67	10.67
12.GA+IAA-900	11.0	13.0	12.0
13.GA+K-300	11.33	14.67	14.33
14.GA+K-600	11.67	11.67	13.3
15.GA+K-900	11.67	15.33	14.0
16.IAA+K-300	11.33	12.0	11.0
17.IAA+K-600	11.0	12.0	11.33
18.IAA+K-900	11.0	12.33	12.67
19.GA+IAA+K-300	9.67	10.67	14.67
20.GA+IAA+K-600	11.0	13.0	13.0
21.GA+IAA+K-900	12.33	12.67	12.0
22. CONTROL	10.0	10.33	13.67
SED	1.060	2.22	1.43
Significance ('F' test)	NS	NS	NS

WAT - Weeks after transplanting.

NS - Not significant.

Table 16: Bulb Diameter (cm) of each Bulb for Plant of Onions as influenced by the Growth Regulators and their Combinations during the Dry Season at Samaru in 1987.

TREATMENTS	4 WAT	8 WAT	12 WAT	16 WAT
1.GA-300	1.156 a-k*	4.15*	6.5.	4.11
2.GA-600	1.34 a	4.17	6.26	5.32
3.GA-900	1.23 a-f	5.64	6.17	5.20
4.IAA-300	1.32 a-d	5.06	6.97	5.53
5.IAA-600	1.24 a-e	5.52	6.0	5.37
6.IAA-900	1.31 a-c	5.23	4.06	5.23
7.K-300	0.02 e-k	4.73	5.17	6.17
8.K-600	1.16 a-h	5.32	6.27	4.2
9.K-900	.9 d-k	5.10	6.4	6.07
10.GA+IAA-300	1.096 a-k	5.9	6.29	6.37
11.GA+IAA-600	.90 d-k	5.03	5.92	6.22
12.GA+IAA-900	1.17 a-i	4.77	4.72	5.15
13.GA+K-300	.70 g-k	5.59	6.71	7.02
14.GA+K-600	1.10 a-g	5.67	6.50	5.45
15.GA+K-900	.96 a-k	4.56	7.13	4.67
16.IAA+K-300	1.09 a-k	5.50	6.64	5.57
17.IAA+K-600	.91 e-k	e.07	6.07	5.2
10.IAA+K-900	.913 b-k	4.54	6.42	6.07
19.GA+IAA+K-300	.89 a-k	6.1	6.05	4.35
20.GA+IAA+K-600	.03 e-k	5.25	5.44	4.99
21.GA+IAA+K-900	.70 k	6.03	5.71	5.57
22. CONTROL	1.33 ab	4.93	6.45	6.06
SED	.10	.98	1.04	1.09
Significance('F'test)	**	NS	NS	NS

*Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significant using DMRT.

Means followed by two letters connected with a hyphen are included in all groupings between the two letters in the alphabet.

WAT - Weeks after transplanting.

NS - Not significant.

** - Significant at 1% level.

Table 17: Leaf area (cm^2) of plant of Onions as influenced by the Growth Regulators and their combinations during the Dry Season at Samaru in 1987.

TREATMENTS	4 WAT	8 WAT	12 WAT
1.GA-300	2.22	10.11	2.55
2.GA-600	2.48	10.56	3.23
3.GA-900	1.70	9.0	3.22
4.IAA-300	2.33	9 .25	2.76
5.IAA-600	2.10	9.5	1.03
6.IAA-900	2.14	6.64	1.45
7.K-300	1.67	11.76	2.30
8.K-600	2.28	10.7	1.3
9.K-900	1.20	13.53	3.02
10.GA+IAA-300	1.64	7.05	2.00
11.GA+IAA-600	2.19	8.29	2.06
12.GA+IAA-900	1.34	13.2	1.46
13.GA+K-300	1.07	8.67	1.66
14.GA+K-600	1.70	8.93	1.60
15.GA+K-900	1.39	8.94	4.32
16.IAA+K-300	1.49	11.86	1.39
17.IAA+K-600	1.21	9.21	2.13
18.IAA+K-900	1.08	9.92	1.92
19.GA+IAA+K-300	1.21	8.16	2.10
20.GA+IAA+K-600	1.27	8.60	2.74
21.GA+IAA+K-900	1.29	10.17	2.50
22. CONTROL	2.19	9.29	2.32
SED	.501	2.271	1.12
Significance ('F' test)	NS	NS	NS

WAT - Weeks after transplanting.

NS - Not significant

Table 10: Bulb dry weight (g) per plant of Onions as influenced by the Growth Regulators and their Combinations during the Dry Season at Samaru in 1987.

TREATMENTS	4 WAT	8 WAT	12 WAT	16 WAT
1.GA-300	.07 a-b*	24.24	20.6	25.2
2.GA-600	1.27 a-b	31.22	33.8	37.0
3.GA-900	1.00 a-g	20.62	34.0	30.4
4.IAA-300	1.01 a-f	29.6	25.2	30.2
5.IAA-600	1.29 a	21.20	25.1	41.0
6.IAA-900	1.23 a-d	20.31	12.3	40.2
7.K-300	.71	29.25	24.7	50.9
8.K-600	.93 a-b	29.45	37.5	20.5
9.K-900	.57 a-h	26.2	42.2	70.0
10.GA+IAA-300	.77 a-h	34.3	35.1	20.3
11.GA+IAA-600	1.25 a-c	20.72	33.2	59.1
12.GA+IAA-900	.86 a-h	29.0	17.6	30.1
13.GA+K-300	.08 a-h	20.3	36.3	55.6
14.GA+K-600	.70 a-h	30.0	77.7	37.2
15.GA+K-900	.64 a-h	26.25	30.4	31.3
16.IAA+K-300	.40 h	22.94	40.9	50.4
17.IAA+K-600	.48 f-h	34.50	31.2	31.4
18.IAA+K-900	.57 a-h	31.63	36.9	45.0
19.GA+IAA+K-300	.77 b-h	25.86	42.3	30.6
20.GA+IAA+K-600	.59 a-h	30.50	31.2	65.7
21.GA+IAA+K-900	.45 f-h	37.4	29.8	41.7
22. CONTROL	1.00 a-e	27.60	46.2	66.2
SED	.25	5.526	14.40	19.5
Significance ('F' test)	**	NS	NS	NS

* Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significant using DMRT.

Means followed by two letters connected with a hyphen are included in all groupings between the two letters in the alphabet.

WAT - Weeks after transplanting.
NS - Not significant.
** - Significant at 1% level.

Application of IAA at 600 ppm gave the highest bulb dry weight but this was not different from the control. The least weight which when compared with the control was significantly different, was obtained from the combination of GA_3 and K at 900 ppm. Other treatments significantly lower than the control were 17 and 21.

4.2.8 Leaf dry weight

There was no significant effect of the growth regulators on the leaf dry weight at 12 WAT while there were differences between the various treatments at 4 WAT.

GA_3 at 600 ppm gave the highest weight followed by IAA at 600 ppm. All the treatments except GA_3 + IAA + K at 900 ppm, which gave the least weight were not significantly different from the control (Table 19).

4.3 Results Obtained from the Graphs Showing Bulb Fresh weight during the Dry Season as affected by the Effects of the Growth Regulators at 300, 600 and 900 ppm.

4.3.1 Mean bulb fresh weight during the dry season at 300 ppm

In Fig. 1, the effect of K was maximum at 8 WAT. The growth regulators GA_3 + K had produced the least weight at 8 WAT.

The control had produced the largest bulk fresh weight

Table 19: Leaf Dry Weight (g) per Plant of Onions as Influenced by the Growth Regulators and their Combinations during the Dry Season at Samaru in 1987.

TREATMENTS	4 WAT	12 WAT
1.GA-300	3.47 a-h*	7.70
2.GA-600	4.25 a	7.46
3.GA-900	2.84 a-h	8.44
4.IAA-300	3.64 a-d	4.02
5.IAA-600	4.05 ab	7.03
6.IAA-900	3.64 a-e	5.01
7.K-300	3.90 ac	6.32
8.K-600	3.39 a-h	5.20
9.K-900	2.1 c-h	8.35
10.GA+IAA-300	3.34 a-h	6.17
11.GA+IAA-600	2.34 b-h	6.07
12.GA+IAA-900	2.30 b-h	6.04
13.GA+K-300	2.3 b-h	6.51
14.GA+K-600	3.20 a-h	6.48
15.GA+K-900	1.07 d-h	9.93
16.IAA+K-300	2.21 c-h	5.62
17.IAA+K-600	1.9 d-h	8.8
18.IAA+K-900	1.86 d-h	7.02
19.GA+IAA+K-300	2.51 a-h	9.25
20.GA+IAA+K-600	2.18 c-h	7.43
21.GA+IAA+K-900	1.62 h	7.36
22. CONTROL	3.59 a-f	7.51
SED	.79	2.04
Significance ('F' test)	**	NS

* Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significant using DMRT.

Means followed by two letters connected with a hyphen are included in all groupings between two letters in the alphabet.

WAT - Weeks after transplanting.
NS - Not significant
** - Significant at 1% level.

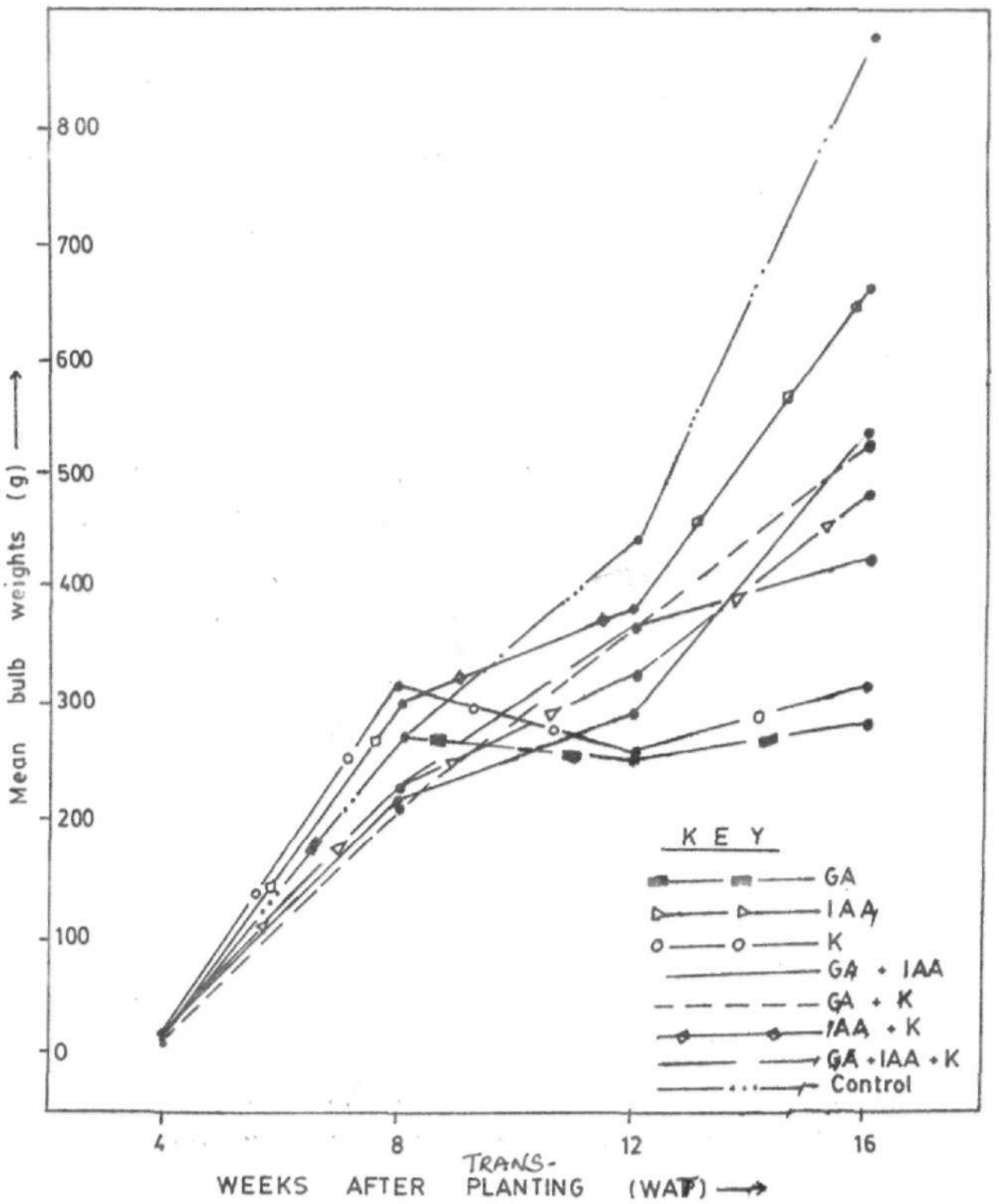


Fig.1: Mean bulb fresh weight (g) during dry season (Jan. — May 1987) at 300 ppm of the growth regulators

followed by IAA + K at 12 WAT. The least weight was produced by GA_3.

The same effects of the growth regulators continued at 16 WAT as at 12 WAT.

4.3.2 Mean bulb fresh weight during the dry season at 600 ppm.

In Fig. 2, IAA had produced the largest weight. The least was produced by GA_3 + IAA + K, at 8 WAT.

During the 12 WAT, the control had produced the largest bulb weight followed by GA_3 + K. IAA + K remained to produce the lowest weight.

Although at 16 WAT the least weight was produced by K, while the control continued to produce the largest weight.

4.3.3 Mean bulb fresh weight during dry season at 900 ppm.

At Fig. 3, it was shown that the growth regulators GA_3 + IAA had produced the largest fresh weight while the least weight was obtained due to GA_3 + K, at 8 WAT.

At 12 WAT, the control produced the largest bulb weight followed by K. The least weight was due to GA_3 + IAA.

At 16 WAT, the effect of the control remained maximum, while GA_3 + K produced the least bulb fresh weight.

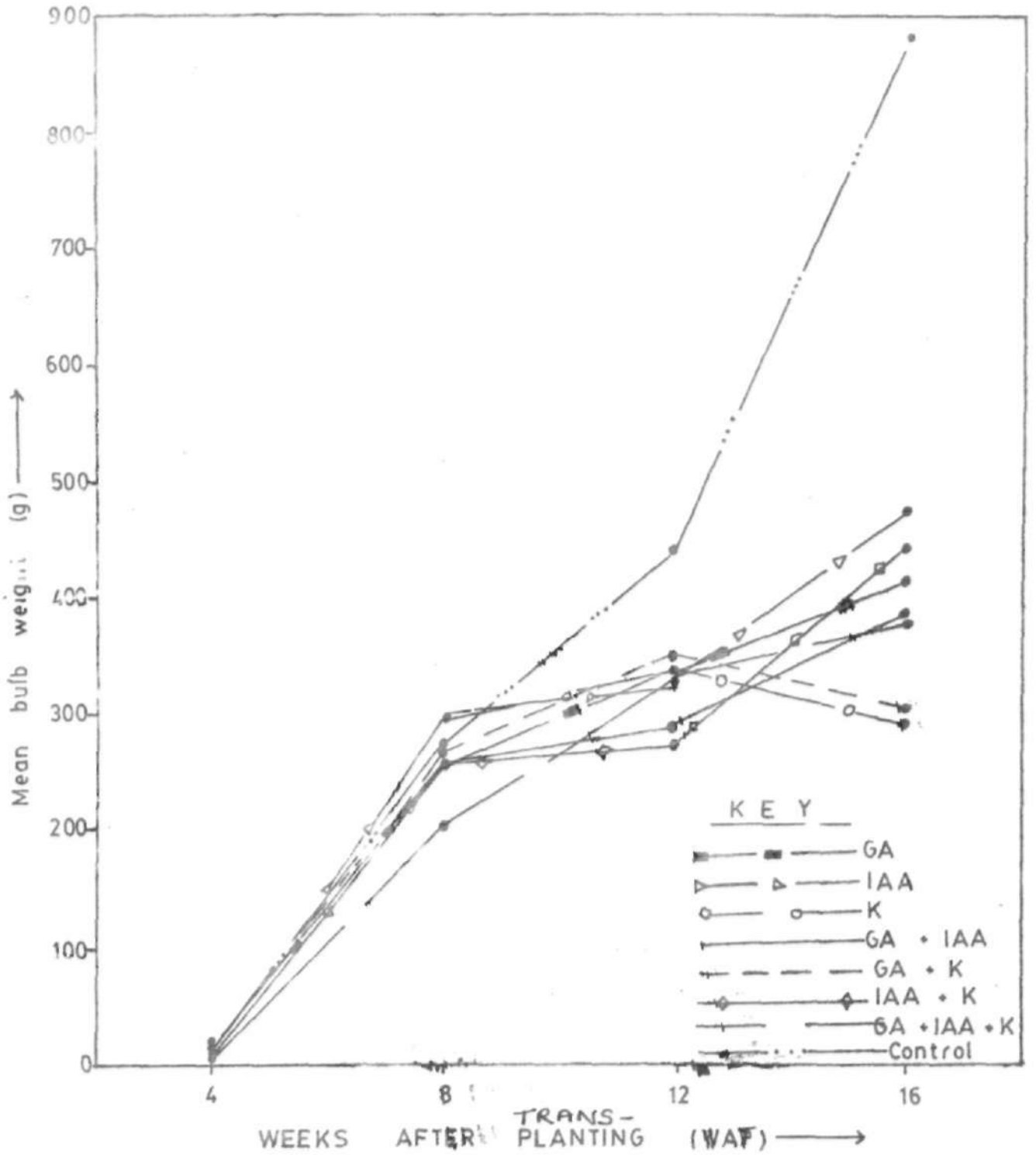


Fig. 2: Mean bulb fresh weight (g) during dry season (Jan. — May, 1987) at 600 ppm of the growth regulators

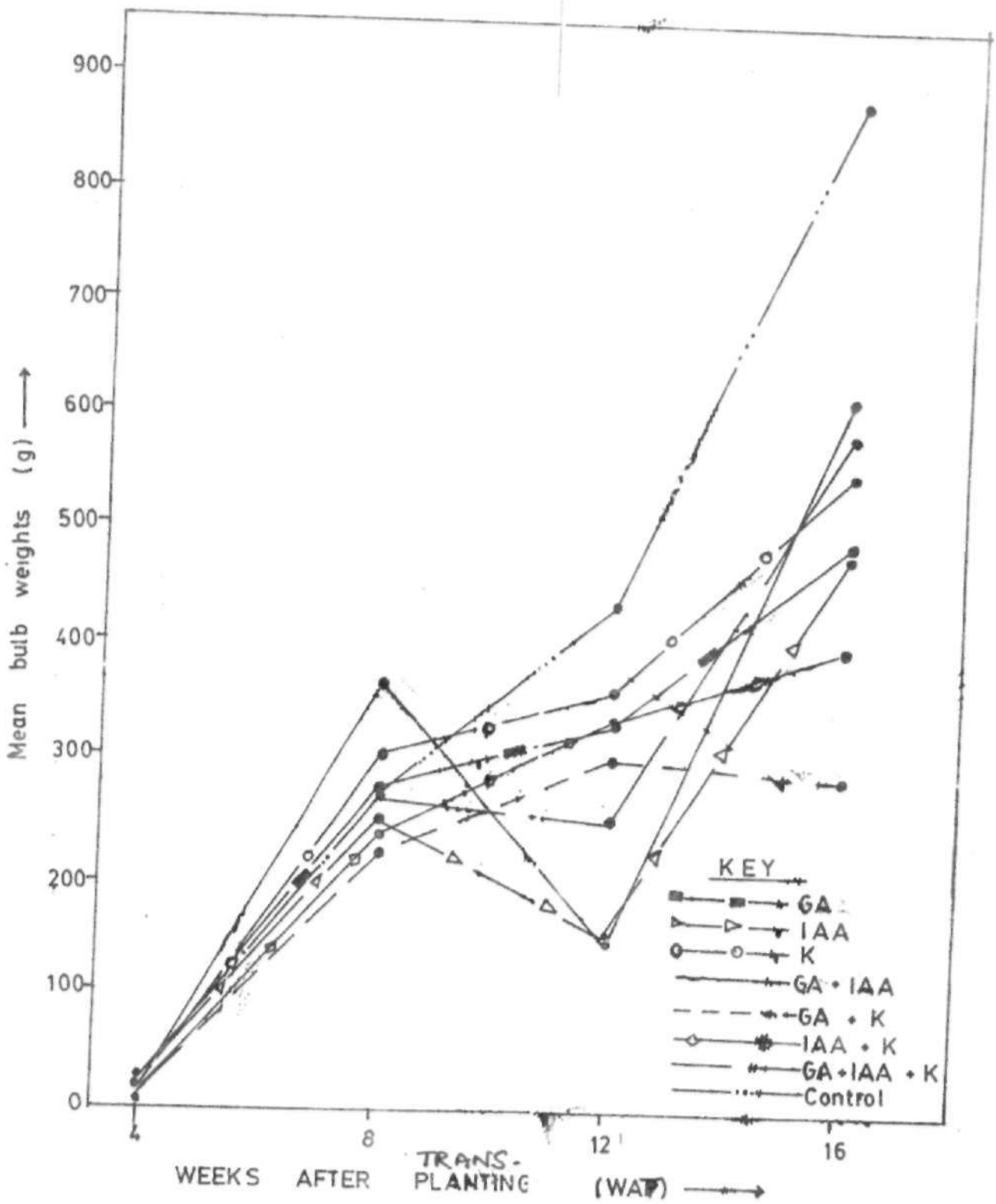


Fig 3: Mean bulb fresh weight (g) during dry season (Jan. – May 1987) at 900 ppm of the growth regulators

Chapter 5.

DISCUSSION

5.1 Effect of GA_3, IAA and K and their Combinations On Growth of Onions during the Wet Season (June - October, 1986)

5.1.1 Total fresh weight as influenced by the growth regulators and their combinations in onions

The onion plants showed maximum response to GA_3 + IAA at 600 ppm during 0 WAT and to GA_3 + K at 300 ppm during 12 WAT. There was no effect obtained at 4 and 16 WAT, with the growth regulators singly or combined at any of the concentrations. These observations are similar to the findings of Isaac (1985) in which GA_3 + IAA significantly increased the growth of onion plants at high concentrations while GA_3 + K increased growth at low concentrations. In other plants such as Azukia beans, GA_3 + IAA caused a stimulation of growth only when the two growth regulators were added together (Shibooka, 1971). Galston and Purves (1960) further noticed that in the presence of GA_3, auxin concentrations increased hence both are required for stimulation of growth.

The effect of GA_3 + K in this trial could be supported by the findings of Delagher - Langhot (1974) who noticed that on potato an increase in growth at concentrations of

300 - 500 ppm. Listowski and Lis (1973) reported that GA_3 + K stimulated the growth of citrus seedlings at a low concentration. Moreover, in tomato, the growth of lateral bud has been reported to be enhanced by the application of GA_3 + K (Catalano and Hill, 1969).

5.1.2 Bulb fresh and dry weights as influenced by the growth regulators and their combinations on onions.

The bulb fresh and dry weights at 8 and 12 WAT were enhanced by GA_3 + K at 300 ppm. This was in confirmity with the findings of Mugge and Richter (1975) who worked on onions and tulip bulbs. They found that the bulb growth was increased and they added furthermore that the bulbs propagation co-efficient was more while dipping the bulbs than a leaf spray of the same mixture. Abohassan et al. (1979) also observed that GA_3 + K increased seedling and fruit growth in apricot and lime fruits.

The application of GA_3 + IAA + K at 900 ppm resulted in inhibition of growth suggesting that the concentration was rather high. It has been shown that very high concentration of GA_3 or K could cause damage to onions by Naamni et al. (1980) when he discovered that GA_3 - treated onions showed an inhibition of growth at a very high concentration of 900 ppm. This was further confirmed by Ram (1979) when GA_3 at a low concentration of 200 ppm gave the largest fruits in guava, while there was inhibition at a higher concentration.

significantly under the treatment of GA_3 at 600 ppm. These results obtained confirmed the findings of Lipe (1975) who noticed that GA_3 at low concentrations produced maximum growth in onions. Olivares and Manuel (1962) also reported that GA_3 was very effective in bringing about an increase in growth of onions. Furthermore, Lipe (1975) reported that GA_3 increased the number of leaves per plant and percentage of plants initiating multiple growing points. The phenomena was also observed in this experiment although a detailed recording was not done.

In other plants, such as potatoes, Perennec and Crosnier (1971) found an increased number, size and yields of tubers when treated with GA_3 further supporting the above work done by Lipe (1975) on initiation of multiple points in onions and also the observation obtained during this research. Rakhimbaev and Ol'shanskaya (1971) also found a sharp increase in growth when GA_3 was applied on garlic bulbs. It has also found that GA_3 stimulated the growth of tomatoes when compared with the untreated control (Castro and Malavolta, 1976). Nesheva (1977) treated seeded grapes cv. Bolgar and seedless grapes cv. Kishmish Khishrau with GA_3, IAA and K. They observed that GA_3, alone, had a significant effect on the weight of the grapes of the two cultivars. Lenz (1974) further confirmed these results, by proving that GA_3 at a low concentration of 100 ppm increased the shoot dry weight of Citrus sp.

5.2.2 Effect of growth regulators and their combinations on bulb fresh weight of the onion plants

The highest bulb fresh weight was produced with the application of IAA at 900 ppm at 4 WAT. This was in conformity with the findings of Isaac (1905) where onion bulbs was significantly increased when treated with IAA at high concentrations. Olivares and Manuel (1962) reported that auxins had a great influence on bulb formation and development in onions. Maximum fruits were obtained in egg plants, when treated with auxins at a high concentration (Siddiqui and Khan, (1970).

In peas, IAA was also found to stimulate growth at higher concentrations while at lower concentrations it inhibited growth (Robinson, 1975). Similar effects of IAA were observed in the present study. Kale and Chujbal (1972) treated hardwood cuttings of Bouginvillea with auxins at 1000 - 2500 ppm, before planting. The treatments were most successful and resulted in 75% growth compared with 15% in untreated cuttings. 100% germination was observed when IAA was treated on pea plants (Rao, 1975).

When the seedlings of onions, during this study, were treated with IAA + K at 300 ppm in the present study, there was an inhibitory effect on the bulb fresh weight. This effect may have been due to the inhibition of K at both lower and high concentrations (Delaghar-Langhot, 1974).

5.2.3 Effect of growth regulators and their combinations on bulb dry weight

Maximum bulb dry weight was obtained when onions were treated with IAA at 600 ppm. This result was similar to the findings of Sinha and Verma (1974) who reported a pronounced increase in growth of Datura innoxia at 1000 ppm of IAA. Work done by El-heboudi and ElMaksoud (1977) on tomatoes treated with IAA further supported the above results. IAA at high concentrations were also found to have a significant increase on bulb weight in onions, (Isaac, 1905). Thomas et al. (1975) also r ported that IAA had a significant effect on cats. Leopold (1981), furthermore, supported the results obtained during this study by reporting that auxins stimulated growth of stems at a rapid rate; it was also found that auxins stimulated the growth of potato tubers and artichokes at a high concentration. Nakamura and Takahashi (1960) showed cell elongation in Pisum sp with treatment of IAA.

5.3 Effect of the Growth Regulators and Combinations on Bulb Fresh Weight during the Dry Season and Wet Season

In the Figs. 1 - 3, it was shown that the control treatment gave the maximum bulb fresh weight, during the dry season, while the treatment with the growth regulators produced the maximum effect on bulb fresh weight during the Wet Season.

This reduced action of the growth regulators during the dry season may have been due to the water stress on the treated plants. Onions do require a large amount of water because of its shallow roots (Jones and Mann, 1963). The demand may have been greater on the plants treated with the growth regulators. The vigorous growth obtained during the wet season could have been also due to the increase effect of growth regulators on the plants infected by twister disease as suggested by Tarr (1972), who reported that whenever a plant pathogen infects a plant, it would derange the balance of the growth regulators and cause abnormal growth in the infected plant. In this study, during the wet season, the onion plants were infected by twister disease. The effect of the pathogens was further confirmed by Ludwig (1952). He found that IAA and GA_3 could stimulate the growth of infected plants of tomatoes. Pathak (1972), furthermore, confirmed the above result by reporting that pathogenesis could alter the metabolism of growth regulators such as IAA, GA_3 and Kinetin. He explained that several fungal and bacterial plant pathogens could synthesize auxins in vitro, and GA_3 or K could cause stimulatory effects on various infected crops. The result of this study showed a similar effect on onions.

Chapter 6.

SUMMARY AND CONCLUSION

Field experiments were conducted during the wet season (June - October, 1986) and the dry season (January - May, 1987) at Samaru in the northern Guinea Savanna ecological zone of Nigeria. This study was done to investigate the effects of the growth regulators; Gibberellic Acid (GA_3), Indoleacetic Acid (IAA) and Kenetin (K) and their combinations at 300, 600 and 900 ppm on onions. These were factorially combined and laid out in a randomized complete block design, with three replications.

During the first experiment the growth regulators had significant effect on the total fresh weight, at 8 WAT, and 12 WAT. The largest total fresh weight was obtained with the application of GA_3 + K at 600 ppm. This treatment also increased bulb fresh weight significantly at 12 WAT.

During the dry season, it was noticed that the growth regulators and their combinations influenced the total fresh weight, bulb and leaf fresh weight and the bulb diameter only at 4 WAT. The largest total fresh weight, the leaf fresh weight, the bulb diameter and leaf dry weight were obtained when GA_3 was applied at 600 ppm. IAA at 900 ppm produced the largest bulb fresh weight at 4 WAT, while the largest bulb dry weight obtained from IAA at 600 ppm.

It can thus be concluded that CA_3, IAA at a higher concentrations and the combinations of CA_3 + K at a lower concentrations was most effective. It has also been found that K had an inhibitory effect at high concentrations while IAA had a stimulatory effect at the same level. IAA was not effective at low concentrations.

The practical implication of this study is that onion farmers in Nigeria may be able to improve upon their yields of the bulbs by the use of the growth regulators at appropriate concentrations.

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APPENDIX 1 KEY TO THE TABLES

TREATMENTS	NUMBERS TO TREATMENTS
GA at 300ppm	1
GA at 600ppm	2
GA at 900ppm	3
IAA at 300ppm	4
IAA at 600ppm	5
IAA at 900ppm	6
K at 300ppm	7
K at 600ppm	8
K at 900ppm	9
GA + IAA at 300ppm	10
GA + IAA at 600ppm	11
GA + IAA at 900ppm	12
GA + K at 300ppm	13
GA + K at 600ppm	14
GA + K at 900ppm	15
IAA + K at 300ppm	16
IAA + K at 600ppm	17
IAA + K at 900ppm	18
GA + IAA + K at 300ppm	19
GA + IAA + K at 600ppm	20
GA + IAA + K at 900ppm	21
Control	22

Appendix 2: Total rainfall, mean temperature, relative humidity and sunshine hours at ten-day intervals during the period of trial at Samaru in 1986.

Month	Days	Total rain-fall (mm)	Relative Humidity (%)		Mean Temperature		Sunshine (hours)
			10.00	16.00	Max.	Min.	
June	1-10	35.0	64.1	51.2	29.9	20.7	7.0
	11-20	22.6	74.3	55.8	30.2	20.6	9.1
	21-30	24.1	75.3	59.0	30.0	20.1	7.4
July	1-10	52.9	79.8	62.0	29.0	20.0	7.0
	11-20	49.4	83.4	67	27.8	19.5	6.5
	21-31	181.3	83.1	73.1	27.0	19.6	5.2
August	1-10	50.6	83.0	76.9	28.1	19.3	5.8
	11-20	94.9	84.3	66.0	28.5	19.7	7.1
	21-31	176.6	78.3	70.5	29.1	19.4	7.7
September	1-10	56.4	77.8	68.9	28.7	19.5	7.1
	11-20	81.2	72.6	64.2	29.3	18.6	8.6
	21-30	75.3	76.4	69.2	29.3	19.1	7.8
October	1-10	0	67.5	56.3	30.4	19.1	7.9
	11-20	0	45.4	45.3	31.5	15.8	9.6
	21-31	0	57.1	48.4	31.4	17.9	8.1
November	1-10	0	49.8	31.0	33.0	17.8	9.0
	11-20	0	24.9	22.4	30.0	12.0	8.5
	21-30	0	33.7	25.8	31.1	12.9	7.3
December	1-10	0	28.6	22.7	26.4	13.0	5.7
	11-20	0	24.3	20.4	27.0	12.4	8.6
	21-31	0	22.4	22.6	27.6	12.5	6.7

Source: Meteorological Unit, Institute for Agricultural Research, Samaru, Zaria, Nigeria.

Appendix 3. Total rainfall, mean temperature, relative humidity and sunshine hours at ten-day intervals during the period of the trial at Samaru in 1987.

Month	Days	Total rainfall (mm)	Relative Humidity (%)		Mean Temperature		Sunshine (hours)
			10.00	16.00	Max.	Min.	
January	1-10	0	21.8	19.2	28.8	11.7	8.5
	11-20	0	18.1	15.7	32.6	11.7	9.8
	21-31	0	24.0	21.4	30.2	13.9	9.2
February	1-10	0	12.9	9.7	30.9	15.0	8.0
	11-20	0	13.7	10.8	32.9	16.6	8.9
	21-31	0	9.9	10.4	34.6	17.5	10.0
March	1-10	0	10.3	7.9	32.7	16.4	9.3
	11-20	0	12.9	14.8	36.1	19.2	6.8
	21-31	0	18.1	25.4	35.6	22.9	4.1
April	1-10	0	29.4	10.6	36.3	20.9	7.7
	11-20	0	19.2	11.2	36.8	21.1	9.2
	21-30	0	6.9	7.8	35.9	23.1	4.1
May	1-10	0	36.0	10.7	38.7	21.3	9.9
	11-20	0	47.7	16.8	38.6	23.4	8.1
	21-31	135.7	66.6	45.6	33.4	22.0	8.5
June	1-10	85.4	81.5	63.5	29.8	20.6	6.4
	11-20	16.2	71.2	53.8	32.1	21.8	8.9
	21-30	45.2	76.7	68.2	30.1	21.0	7.5

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