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Full Length Research paper

Evaluation of the biochemical effects of auxins on nutritional quality of tomato (*Solanum lycopersicon*), genotype JM 94/47

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The effect of Indole-3- acetic acid (IAA), Indole-3-butyric acid (IBA) and Naphthalene acetic acid (NAA) at 60, 100 and 140 mg/L was evaluated on some biochemical indices of the nutritional quality of tomato (*Solanum lycopersicon*). The parameters evaluated were crude proteins, crude fat, crude fibre, ash, dry matter, titratable acidity, total carbohydrate, total soluble solids (°Brix), pH and °Brix/Acid ratio. The results showed that all the concentrations of IAA, IBA and NAA increased the levels of crude proteins, crude fat, crude fibre, ash, titratable acidity but decreased the total carbohydrate content. A decrease in dry matter content was evident in 60 mg/L of IAA, IBA, NAA and 100 mg/L of NAA. The pH of tomato pulp decreased in treatments involving 100 mg/L of IAA and 140 mg/L of IAA and NAA respectively. The total soluble solid content and °Brix/Acid ratio were significantly higher ($P < 0.05$) in the 100 mg/L NAA treatment. The results indicated that the bioregulators could enhance the basic tomato nutrients of importance in human diet.

Key words: Indole-3-acetic acid, indole-3-butyric acid, naphthalene acetic acid, nutritional quality, tomato.

INTRODUCTION

Tomato is a member of the Solanaceae family, genus *Lycopersicon* (Britannica, 1990). It is one of the most widely cultivated economically important vegetable in the world. Botanically, tomatoes are fruits (berry), but they are commonly referred to as vegetable. They are often eaten raw or cooked and are often processed to make tomato paste, sauce, ketchup or juice. Tomatoes probably originated in the Peru-Equador region and are now in most climatic zones in Africa, tropical Asia, tropical America and the tropics (Kroll, 1997). Tomatoes are consumed widely throughout the world and their consumption has recently been demonstrated to possess health benefits because of its rich content of phytonutrients (Levy and Sharoni, 2004; Hsu et al., 2008). Epidemiological studies suggest that intake of tomatoes or processed tomato products in particular lowers the risk of prostate cancer (Giovannucci et al., 1995; Campbell et al., 2004).

Bioregulators affect fundamental processes of plant growth and development. Indole-3-acetic acid (IAA), Indole-3-butyric acid (IBA) and Naphthalene acetic acid (NAA) are plant bioregulators belonging to the auxin group. Plant bioregulators are organic compounds, either natural or synthetic that modifies or controls one or more specific physiological processes within a plant. They can accelerate or retard the growth or maturation rate or otherwise alter the behaviour of plants or their products (Lemaux, 1999; Olaiya and Osonubi, 2009). Bioregulators are used to advance or delay fruit harvest by influencing fruit maturation and ripening (Looney, 1998). The phytonutrients in tomato fruit are influenced by a number of factors such as varietal or clonal, genetics, agronomic, seasonal and cultural factors (Villareal, 1978). Although there are reports on varietal, seasonal and fertilizer application on chemical constituents of fruits

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(Alleyne and Clark, 1997; Olienyk et al., 1997; Ruiz and Romero, 1998b), studies on the effect of bioregulators on tomato phytonutrients is scanty, especially in the Black African sub – continent. This study was conducted to evaluate the biochemical effects of the plant bioregulators IAA, IBA and NAA on nutritional quality of tomatoes.

MATERIALS AND METHODS

Seed source and fruit type

The tomato seeds were obtained from the National Horticultural Research Institute (NIHORT), Idi-Ishin, Ibadan, Oyo State, Nigeria (long 3°50^1 – 52^{1}E and lat. 7°23^1 – 25^{1}N of the equator). The fresh tomato fruits of genotype JM 94/47, NIHORT breed are lobed or irregular and deep red in colour.

The bioregulators used

The three bioregulators Indole-3-acetic acid (IAA), Indole-3-butyric acid (IBA) and Naphthalene acetic acid (NAA) used in the present study were procured from Sigma.

Fifteen (15) mg, 25 mg and 35 mg of each of the respective bioregulator was dissolved in ethanol containing 0.5 ml Tween 20 and the final volume was made up to 250 ml with distilled water to give concentrations of 60, 100 and 140 mg/L respectively.

All the prepared solutions for IAA, IBA and NAA were stored in the dark for 24 hours at ambient temperature (23 - 27^{O}C) after which the tomato seeds (JM 94/47) were soaked into each concentration of the prepared graded doses of the bioregulators in separate Petri dishes for another 24 h. The control experiment involves soaking of the tomato seeds in distilled water.

Raising of the tomato seedlings

The tomato seeds were planted in seedling tray (300 x 200 x 60 mm) containing loamy, well drained, fertile and good moisture retaining capacity soil having 1.0 – 1.5% organic matter in a shaded area so as to raise seedlings for transplanting.

Transplanting

The seedlings were transplanted into polythene bags containing loamy well drained and fertile soil 30 - 40 days after sowing. It takes 10 - 14 weeks for tomatoes to fruit and the fruits to ripe. The plants were grown according to normal cultural practices without application of insecticide or fertilizer. The experimental design was a randomized complete block with four treatments including the control and three replicates.

Sampling

The tomato fruits failed to ripe uniformly when allowed to self ripe, the fruits do not ripe uniformly. The orange – red ripe tomato fruits were picked every morning and stored in resealable plastic bags at 20°C until use. The fruits were rinsed with distilled water and allowed to drain for 5 min. Four whole tomato fruits were put in mortar, mashed, homogenized and stored at 2 – 5°C. Parametric analyses were done within 2 days at the Institute of Agricultural Research and Training (IAR& T), Ibadan, Nigeria.

Analytical procedure

The proximate composition of the tomato fruits like crude protein, crude fibre, ash, crude fat, dry matter (DM) and the titratable acidity (TTA) were determined by Standard methods (AOAC, 1999).

Estimation of the Total Carbohydrate Content: Total carbohydrate content was calculated using the formula:

% Total carbohydrate = 100 - % CP, CF and CA

Where; CP = crude protein, CF = crude fat and CA = crude ash.

pH Determination: About 20 g of the tomato fruit samples was macerated in a pestle with 80 ml of distilled water. The mixture was homogenised for 2 min at maximum speed (Steinkraus et al., 1960) and the pH of the homogenate read directly on a Metrohm – Herisau pH meter, model E-520.

Determination of Total Soluble Solids, TSS (^{0}Brix): Portions of the fruit homogenate were rapidly heated to 80°C in a water bath with constant stirring and stored at 7°C (Paredes – Lopez et al., 1987). The homogenates were then centrifuged at 6,000 rpm at 10 to 12°C for 30 min and filtered through Whatman No. 1 filter paper to obtain the soluble extracts. Total soluble solids were determined for each sample by drying 5 ml of the filtrate at 70°C for 48 h and were expressed as % TSS.

Statistical Analysis

All data obtained were analysed using analysis of variance (ANOVA) Statistica Software (Statistica, 1997). A significant level of 0.05 was used for statistical tests.

RESULTS AND DISCUSSION

The results of effects of the bioregulators on ash, dry matter, pH and titratable acidity of the tomato genotype studied are presented in Table 1. The ash content was higher compared to control in all bioregulator treatments with the maximum values of 0.75, 0.78 and 0.82% in the IBA, IAA and NAA treatments respectively in the tomato genotype. Dry matter content ranged from 10 to 14% and was reduced by 60 mg/L dose of the bioregulators as well as 100 mg/L of NAA relative to control. Fruits in 140 mg/L of bioregulator concentrations consistently had non – significantly higher dry matter content than control. This finding implies a faster water import rate relative to control and is also an important factor for dry matter import in fruits (Bussieres, 1993).

The pH is an important measurement of palatability of any foodstuff. The pH of the tomato genotypes was acidic with low values between 3.50 and 4.80 (Table 1) . Fruit pH did not vary significantly ($P > 0.05$) between treatments. The acidic pH values obtained in this study is characteristic of most fruits and this influences the shelf-life quality by restricting the microflora to acid - tolerant microorganisms (Bracket, 1994).

Titratable acidity was increased with increasing concentrations of IBA and NAA. However, the percentage titratable acidity was reduced with increasing concentration

Table 1. Effects of bioregulators on ash, dry matter, pH and titratable acidity of tomato, genotype JM 94/47*.

Bioregulator	Bioregulator conc. (mg/L)	Ash (%DM)	Dry matter (%)	pH	Titratable acidity (%)
IBA	60	0.53 ± 0.10	11.0 ± 0.04	4.80 ± 0.12**	0.17 ± 0.13
	100	0.75 ± 0.09	12.1 ± 0.02	4.50 ± 0.08	0.18 ± 0.11
	140	0.62 ± 0.17	14.0 ± 0.10	3.90 ± 0.12	0.28 ± 0.11
IAA	60	0.51 ± 0.12	10.0 ± 0.10	4.10 ± 0.14	0.31 ± 0.06**
	100	0.78 ± 0.08	12.0 ± 0.09	3.80 ± 0.11	0.23 ± 0.10
	140	0.69 ± 0.05	14.0 ± 0.13	3.50 ± 0.07	0.17 ± 0.10
NAA	60	0.67 ± 0.11	11.0 ± 0.11	4.30 ± 0.09	0.10 ± 0.07
	100	0.82 ± 0.02**	11.3 ± 0.15	3.90 ± 0.11	0.10 ± 0.15
	140	0.73 ± 0.09	14.0 ± 0.20	3.60 ± 0.10	0.30 ± 0.06
Control		0.49 ± 0.07	12.0 ± 0.14	3.90 ± 0.11	0.09 ± 0.09

*Values are mean ± S.E. (n = 3); DM = Dry matter. **Significantly different from others in the column ($P < 0.05$).

Table 2. Effects of bioregulators on protein, fibre and fat contents of tomato, genotype JM 94/47*.

Bioregulator	Bioregulator conc. (mg/L)	Crude protein (%DM)	Crude fibre (%DM)	Crude fat (%DM)
IBA	60	1.40 ± 0.09	1.43 ± 0.23	1.29 ± 0.17
	100	2.80 ± 0.12**	1.68 ± 0.19	1.57 ± 0.21
	140	1.93 ± 0.17	1.52 ± 0.15	1.46 ± 0.14
IAA	60	1.80 ± 0.07	1.23 ± 0.21	1.41 ± 0.16
	100	2.50 ± 0.11	1.55 ± 0.30	1.61 ± 0.23
	140	2.10 ± 0.09	1.41 ± 0.13	1.52 ± 0.12
NAA	60	1.60 ± 0.08	1.52 ± 0.27	1.18 ± 0.13
	100	2.30 ± 0.19	1.76 ± 0.31**	1.43 ± 0.20
	140	2.10 ± 0.11	1.63 ± 0.29	1.31 ± 0.18
Control		1.20 ± 0.07	1.08 ± 0.11	1.06 ± 0.15

*Values are mean ± S.E. (n = 3); DM = Dry matter; **Significantly different from others in the column ($P < 0.05$).

of IAA with the 60 mg/L concentration giving a statistically higher ($P < 0.05$) value of 0.31%. Titratable acidity determination serves as a measure of fruit acidity (Akl et al., 1995). The level of acidity in tomato fruits is an important index of tartness or sour flavour. The 60 mg/L IAA treated samples are therefore expected to exhibit the highest degree of tartness. Crude protein increased in all bioregulator treatments relative to control and the 100 mg/L dose of IBA gave a significantly higher ($P < 0.05$) value of 2.80% DM (Table 2). The enhancement of the crude protein levels in test tomatoes especially in the 100 mg/L IBA-treatment confirms the previous work of Nandi et al. (1995) who reported increased amino acid and protein contents in tea shoots and in oak tissues following bioregulator applications. The increase in protein content may be as a result of the stimulation of amino acid incorporation into proteins during ripening (Rhodes, 1980). The increase is thus an indication of high amino acid synthesis in such fruits (Scott and Barbow, 1979; Ruiz and Romero,(1999b) The crude fibre content of treated genotypes ranged from 1.23% to 1.76% DM and was enhanced in all treatments relative to control (Table 2). Fibre is reported to help in the rolling of faecal matter into solid bulky mass thereby making it easy to pass out (Puperez and SauraCalixto, 2001). The 100 mg/L NAA – treated tomatoes with statistically significant ($P < 0.05$) crude fibre content of 1.76% DM is therefore expected to be more useful in relieving constipation and other diseases such as carcinoma of the colon and rectum, atherosclerosis and diverticulosis (Davidson et al., 1975; Beecher, 1999). It has been observed that a high incidence of colon cancer was found to be related to the lack of fibre in Western diets; and in Africa where fibre is a major part of the local diets, colon cancer is almost non-existent (Ernest and Rosenbaum, 1982). This is explained by the fact that fibre absorbs liquids and is not digestible and passes rapidly through the gastrointestinal tracts. Thus, as fibre increases the bulkiness and hastens bowel movements, it reduces the

Table 3. Effects of bioregulators on total carbohydrate, total soluble solids and °Brix/Acid ratio of tomato, genotype JM 94/47*.

Bioregulator	Bioregulator conc.(mg/L)	Total carbohydrate (g/100gdwb)	Total soluble solids (°Brix)%	°Brix/Acid** Ratio
IBA	60	96.64 ± 0.12ab	3.50 ±0.40b	20.59 ±0.15b
	100	94.77 ±0.31a	3.80 ±0.30bc	21.11 ±0.23b
	140	95.93 ±0.23a	3.60 ±0.60bc	12.86 ±0.11a
IAA	60	96.46 ±0.34ab	3.40 ±0.20b	10.97±0.17a
	100	95.17 ±0.13a	3.30 ±0.30b	14.35±0.10ab
	140	95.80 ±0.17a	3.41 ±0.70b	20.06±0.25b
NAA	60	96.21 ±0.28ab	3.60 ±0.10bc	36.00±0.30bc
	100	95.12 ±0.32a	3.97 ±0.20c	39.70±0.21c
	140	95.54 ±0.11a	3.50 ±0.60b	11.67±0.15a
Control		97.23 ±0.20b	2.90 ±0.20a	32.22±0.12bc

*Values are mean ± S.E. (n = 3); Means with different letters in a column are significantly different (P< 0.05). **Titratable acidity.

exposure time of the gut linings to waste products like the bile metabolites that may be carcino-genic (Franceshi et al., 1994; Nkondjock et al., 2005).

Crude fat content was not significantly affected (P > 0.05) by the treatments in comparison with the control and were generally low with values ranging between 1.18 and 1.61% DM. Low fat decreases the risk of coronary heart diseases and certain forms of cancer (Gardner et al., 2007).

Data presented in Table 3 shows that the total carbo-hydrate content of the tomatoes treated with the bioregulators were statistically lower (P < 0.05) as compared to the control. The least value of 94.77 g/100 gdwb was obtained in the 100 mg/L IBA treatment. This suggests that application of these bioregulators suppress the photosynthetic process through their influence on certain enzymatic action (Wei et al., 2009). The suppres-sion might be responsible for the observed decrease in carbohydrate content (Haba et al., 1985).

The soluble solid content is a parameter determinant of fruit quality (Alleyne and Clark, 1997) and is an important criterion for selecting tomato genotypes for processing and canning. The values of 3.30% to 3.97% obtained for the test tomatoes and the soluble solid content was significantly (P < 0.05) higher in treated samples relative to the control (Table 3).

The brix – to - acid ratio is an important characteristic for the tomato since it is an indication of sweetness with implications on the flavour and the eating quality (Fawzia et al., 1999). The higher the brix- to- acid ratio, the higher is the palatability and flavour which are the attributes preferred by consumers and manufacturers in tomato. In this study, only NAA at 60 and 100 mg/L gave significantly higher (P < 0.05) brix– to- acid ratio than control (Table 3). As sweetness and sucrose content has been shown to be positively correlated (Alasalvar et al., 2001), it can therefore be inferred that the 100 mg/L NAA -treated tomatoes will have the highest sucrose content among the tomatoes raised in different treatments. This therefore, suggests that they will be of higher palatability than the others and would be preferred by consumers.

The results showed that all the bioregulators (IAA, IBA and NAA) at all concentrations influenced the bioche-mical parameters of tomato fruit. Bioregulators have been reported to influence plant physiological processes (Looney, 1998; Khan et al., 2006). Exogenous application of gibberellic acid (GA), a plant bioregulator increases the rate of germination of seeds and plant growth regulators like IAA, IBA and NAA accelerate fruit setting, ripening and reduce fruit dropping (Grierson and Kader, 1986; Lea and Leegood, 1999) . The observed effects of the bioregulators reported in the present study have many biochemical implications in the sense that nutrients level in the tomato fruit is enhanced. These nutrients are effective in decreasing the risk of some diseases and building of body tissues (Visioli et al., 2003; Riso et al., 2006). Plant bioregulators could therefore be used as a tool for improving the cultivation and consumption of tomatoes through maximizing the nutritional qualities/ potentials of this food crop and thus serve as advance-ment towards the attainment of global food security.

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