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Effect of iodine biofortification on incidence and severity of Fusarium wilt and yield of tomato (*Solanum lycopersicum* L.)

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Abstract

Tomato is often attacked by wilt caused by *Fusarium oxysporium*. Iodine is known to have fungistatic effect in pathogen control. The present experiment was aimed at determining the effect of iodine compounds (potassium iodide, KI and potassium iodate, KIO_3) on incidence and severity of *Fusarium* wilt and yield of two tomato accessions, FUNAABTO/106 and FUNAABTO/123. The experiment was conducted in the screenhouse and on the field. KI was applied at concentrations of 1, 2, 3, 5 mM while KIO_3 was applied at concentrations of 0.5, 1, 2, 3 mM. The untreated plots served as control. Results showed that FUNAABTO/106 treated with 0.5 mM KIO_3 in the screenhouse and on the field had the least (0.00%) disease incidence. Disease severity was significantly ($p \leq 0.05$) lower (1.00) in the screenhouse in pots containing FUNAABTO/106 treated with 1 mM KIO_3. On the field, FUNAABTO/106 treated with 0.5 mM KIO_3 had the least (1.17) disease severity. FUNAABTO/106 treated with 0.5 mM KIO_3 in the screenhouse and on the field were significantly higher (1.65t/ha and 18.54t/ha respectively) in yield. The study concluded that application of iodine compounds at lower concentrations reduced the incidence and severity of *Fusarium* wilt and increased the yield of tomato.

Keywords: Potassium iodate (KIO_3), Potassium iodide (KI), *Fusarium oxysporium*

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Introduction

Tomato, *Solanum lycopersicum* L., is the world's most highly consumed vegetable due to its status as a basic ingredient in a large variety of raw, cooked or processed foods. It belongs to the family Solanaceae. Tomato is grown worldwide for local use or as an export crop. In 2014, the global area cultivated with tomato was 5 million hectares with a production of 171 million tonnes, the major tomato-producing country being the People's Republic of China. (FAOSTAT, 2017). *Fusarium* wilt, caused by *Fusarium oxysporum* f.sp. *lycopersici*, is part of the factors responsible for low production of tomato in Nigeria (Akaeze et. al., 2017). It constitutes serious threat to food security in Sub-Saharan Africa (Popoola et. al., 2012). It causes an average yield loss of 50 % in tomato production (Ajilogba et. al., 2013). Iodine-based compounds have been reported to be effective in controlling some fungal diseases of tomato (Lantz, 2003). Iodine is absorbed by the root and in aerial structures both by the stomata and by the cuticular waxes (Tschiersch et. al., 2009). Then, when absorbed, it is transported through the xylem, and it accumulates in greater amounts in leaves (Lawson et. al., 2015). Iodine is considered as a plant protecting agent and considered less dangerous to the environment (Lantz, 2003). There is a great reduction in yield of tomato globally, and part of the reduction is caused by *Fusarium* wilt (Singh and Kamal, 2012). Fungicides are mostly used in controlling this disease which poses high risk to human health and the environment. However, there is need for eco-friendly control strategies that could reduce the amounts of synthetic fungicides usage. An alternative method is the use of iodine compounds. Adams et. al. (2003) and Lantz (2003) reported the positive effect of iodine to control *Fusarium* wilt of Basil and *Botrytis cinerea* of tomato respectively. The aim of this study was to determine the effect of Potassium iodide (KI) and Potassium iodate (KIO_3) on the incidence and severity of *Fusarium* wilt and yield of two tomato accessions.

Materials and Methods

Experimental sites

The experiment was carried out at Institute of Food Security, Environmental Resources and Agricultural Research Farm, (IFSERAR), Federal University of Agriculture Abeokuta (FUNAAB), Ogun State and Tomato Research Screenhouse, College of Plant Science and Crop Production, Federal University of Agriculture, Abeokuta, Ogun State.

Experimental materials, treatments and experimental design

Tomato seeds of FUNAABTO/0106 and FUNAABTO/0123 accessions obtained from Tomato Germplasm Centre, Plant Tissue Culture Laboratory, FUNAAB, Ogun State were used for the experiment. Potassium iodide (KI) and Potassium iodate (KIO_3) were sourced from a local agrochemical store in Abeokuta. Completely randomized design was used for the screenhouse experiment in three replications while randomized complete block design was used for the field experiment in three replications. The experiment consisted of two tomato accessions, two sources of iodine (KI and KIO_3), four levels of concentrations of each of the iodine sources, the treatment was applied by drenching method. Untreated control plots received neither KI nor KIO_3.

Soil sterilization, nursery establishment and transplanting

Sandy loam soil was steam- sterilized for 3 hours at 100 °C. The sterilized soil was packed inside sacks and left for 2 weeks before use. Fifteen grams (15 g) of the sterilized soil was weighed and loaded in the nursery trays and tomato seedlings were grown and nurtured for four (4) weeks before transplanting. Four weeks old tomato seedlings were transplanted to plastic pots containing 9 kg sterilized soil and placed in the screenhouse. Two tomato seedlings were transplanted into each pot which was later thinned to one. There were fifty- four (54) pots altogether for the screenhouse experiment. Transplanting of tomato seedlings on the field was done in the evening on the already prepared land. The experimental plot size was 3 x 2 m^2 with 1 m border. Tomato seedlings were transplanted at 75 cm x 50 cm spacing. There were fifty- four (54) plots with sixteen (16) plants per plot.

Application of Potassium iodide and Potassium iodate

Tomato plants were treated with KI or KIO_3 at 2, 4, 6 and 8 weeks after transplanting. The treatments were applied by drenching method. Eight iodine concentrations were prepared. KI was applied at 1, 2, 3, and 5 mM concentrations while KIO_3 was applied at 0.5,1, 2 and 3 mM concentrations. Control pots and plots receive no iodine treatments.

Data collection and analysis

Data were collected on the following parameters: disease incidence (%), disease severity and yield (tons/hectare). Data was subjected to analysis of variance (ANOVA), using Statistical Analysis System (SAS), 9.1 package and means were separated using the Duncan's Multiple Range Test ($p \leq 0.05$).

Results

Plate description of Fusarium oxysporum f.sp. lycopersici

Plate culture was fluffy white mycelia growth with aerial growth on the top (Plate 1A). While at the base side of the petri dish, a pinkish pigmented growth was observed from the point of inoculation. In plate 1B, micrograph slides shows that microconidia are borne on simple phialides arising laterally and are abundant, oval–ellipsoid, straight to curve in 4-12 x 2.1-3.5 µm in size. Macroconidia were borne on branched conidiophores or on the surface of sporodochia and are thin walled, three to five septate, fusoid-subulate and pointed at both ends, have pedicellate base. Chlamydospores, both smooth and rough walled which are abundant and form terminally or on an intercalary basis.

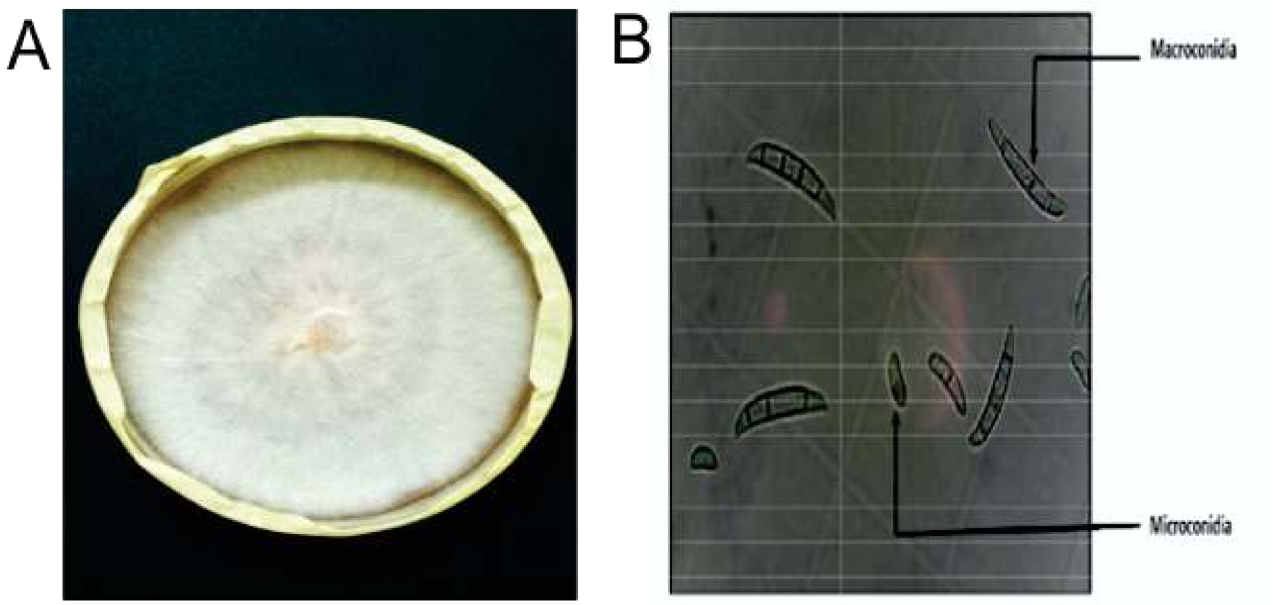

Plate 1: seven (7) days old growth of the pathogen *Fusarium oxysporum* f.sp *lycopersici* (A): Conidia of pathogen on haemocytometer (B)

Effect of iodine compounds on Fusarium wilt disease incidence and severity of tomato

Table 1 shows the effect of iodine compound on tomato fungal wilt incidence.. There were significant differences ($p \leq 0.05$) as the highest disease incidence (50.00 %) in the screenhouse was recorded in the control pot for FUNAABTO/106 and FUNAABTO/123 treated with potassium iodide (KI) at concentration 5 mM at 6 WAT while FUNAABTO/106 treated with potassium iodate (KIO_3) at concentrations 0.5 mM and 1 mM as well as FUNAABTO/123 treated with KIO_3 at 0.5 mM had the least (0.00 %). On the field, the highest disease incidence (43.44 %) at 6 WAT was recorded in FUNAABTO/123 treated with KI at concentration 5 mM while the least result (0.00 %) was recorded in FUNAABTO/106 treated with KIO_3 0.5 mM and 1 mM. Furthermore, at 8 WAT, highest disease incidence (83.33 %) in the screenhouse was recorded in the control pot for FUNAABTO/106 and when treated with KI at concentration 5 mM while the least (0.00 %) was recorded in FUNAABTO/123 treated with KI at concentration 1 mM. Highest disease incidence (60.00 %) on the field at 8 WAT was recorded in FUNAABTO/123 treated with KI at concentration 5 mM while the least was recorded in FUNAABTO/106 treated with KIO_3 at concentrations 0.5 mM and 1 mM.

The effect of iodine compound on tomato fungal wilt severity was shown in Table 2. There was significant difference ($p \leq 0.05$) as the highest disease severity (3.00) in the screenhouse was recorded in the control pot for FUNAABTO/106 and FUNAABTO/123 treated with potassium iodide (KI) at concentration 5 mM (3.67) at 6 WAT while FUNAABTO/106 treated with potassium iodate (KIO_3) at concentrations 0.5 mM and 1 mM as well as FUNAABTO/123 treated with KIO_3 at 0.5 mM and potassium iodide at 1 mM had the least (1.00). On the field, the highest disease severity (4.17) at 6 WAT was recorded in FUNAABTO/123 treated with KI at concentration 5 mM and in its control plot while the least result (1.00) was recorded in FUNAABTO/106 treated with KIO_3 0.5 mM and 1 mM. Furthermore, at 8 WAT, highest disease severity (4.67) in the screenhouse was recorded in the control pot for FUNAABTO/106 while the least (1.00) was recorded in FUNAABTO/106 treated with KI at concentration 1 mM. Highest disease severity (5.17) on the field at 8 WAT was recorded in the control plot for FUNAABTO/123 while the least (1.17) was recorded in FUNAABTO/106 treated with KIO_3 at concentrations 0.5 mM.

Effect of iodine compounds on fruit yield of tomato

Iodine compounds influenced tomato yields significantly in the screenhouse and field trials. (Table 3). Yield from field was higher than screenhouse. The highest (1.65 t/ha) yield of tomato in the screenhouse was produced under a treatment of potassium iodate at concentration of 0.5 mM in FUNAABTO/106 accession while the control pot for FUNAABTO/106 had the least (0.95 t/ha) yield. FUNAABTO/106 treated with potassium iodate at concentration of 0.5 mM had the highest (18.54 t/ha) yield on the field while the least (4.16 t/ha) yield was recorded in the control pot for FUNAABTO/123.

TABLE 1: Effect of iodine compounds on incidence of *Fusarium* wilt of tomato

Accession	Treatment (mM)	6 WAT Screenhouse	6 WAT Field	8 WAT Screenhouse	8 WAT Field
FUNAABTO/0106	Control	50.00a	26.67b	83.33a	40.00b
	KI- 1	16.67b	3.33bd	33.33b	3.33bcd
	KI- 2	16.67b	16.67bc	33.33b	20.00bc
	KI- 3	33.33a	23.33b	50.00b	36.67b
	KI- 5	40.67a	36.67a	83.33a	50.00a
	KIO_3 - 0.5	0.00b	0.00bcd	16.67bc	0.00bcd
	KIO_3 – 1	0.00b	0.00bcd	33.33b	0.00bcd
	KIO_3 -2	16.67b	3.33bcd	33.33b	26.67bc
	KIO_3 – 3	16.67b	20.00b	50.00b	33.33b
FUNAABTO/0123	control	33.33a	40.00a	66.67a	53.33a
	KI- 1	0.00b	6.67bcd	0.00bc	16.67bc
	KI- 2	16.67b	16.67bc	33.33b	20.00bc
	KI- 3	33.33a	30.00b	50.00ab	33.33b
	KI- 5	50.00a	43.33a	50.00ab	60.00a
	KIO_3 - 0.5	0.00b	3.33bcd	16.67b	3.33bcd
	KIO_3 - 1	16.67b	3.33bcd	16.67b	20.00bc
	KIO_3 / 2	16.67b	6.67bcd	33.33b	10.00bcd
	KIO_3 / 3	33.33a	10.00bc	50.00ab	16.67bc

Means in the same column with different alphabet are significantly different (p<0.05) according to Duncan's Multiple range test

TABLE 2: Effect of iodine compounds on severity of *Fusarium* wilt of tomato

		SEVERITY			
		6 WAT		8 WAT	
Accession	Treatment (mM)	Screenhouse	Field	Screenhouse	Field
FUNAABTO/0106	Control	3.00a	3.00b	4.33ab	4.17a
	KI- 1	1.33bc	1.17bcde	2.00bc	1.33bcd
	KI- 2	1.67b	1.50bcde	3.00b	2.67bc
	KI- 3	2.00b	2.33bcd	4.00ab	3.50b
	KI- 5	2.67a	4.00a	4.67a	4.50a
	KIO_3 - 0.5	1.00bc	1.00bcde	2.00bc	1.17bcd
	KIO_3 – 1	1.00bc	1.00bcde	1.00bcd	1.33bcd
	KIO_3 -2	1.33b	2.33bcd	2.33bc	2.17bc
	KIO_3 – 3	1.67b	2.83bc	3.33b	3.33b
FUNAABTO/0123	control	2.67bc	4.17a	3.67a	5.17a
	KI- 1	1.00bcd	1.33bc	2.00b	2.33bc
	KI- 2	1.67bc	1.50bc	2.04b	2.67bc
	KI- 3	2.00bc	3.33b	3.67a	3.83b
	KI- 5	3.67a	4.17a	4.00a	5.00a
	KIO_3 - 0.5	1.00bcd	1.17bcd	2.00b	1.33bcde
	KIO_3 - 1	1.33bc	1.17bcd	2.33b	2.17bcd
	KIO_3 / 2	1.67bc	1.50bc	2.00b	2.33bc
	KIO_3 / 3	2.00bc	1.67bc	3.00a	2.83bc

Means in the same column with different alphabet are significantly different (p<0.05) according to Duncan's Multiple range test

Table 4: Effect of iodine compounds on the yield of tomato

Accession	Treatment (mM)	YIELD OF TOMATO (tons/ha) Screenhouse	Field
FUNAABTO/0106	Control	0.95[bcd]	5.90[bcdef]
	KI- 1	1.51[b]	14.77[b]
	KI- 2	1.49[b]	13.96[bc]
	KI- 3	1.25[bc]	10.78[bcd]
	KI- 5	1.06[bc]	6.87[bcde]
	KIO_3 - 0.5	1.65[a]	18.54[a]
	KIO_3 – 1	1.60[ab]	15.75[b]
	KIO_3 -2	1.41[b]	11.39[bcd]
	KIO_3 – 3	1.17[bc]	7.57[bcde]
FUNAABTO/0123	control	1.15[bc]	4.16[bcdef]
	KI- 1	1.46[a]	13.71[bc]
	KI- 2	1.37[b]	12.37[bcd]
	KI- 3	1.23[bc]	10.20[bcde]
	KI- 5	1.09[bc]	8.39[bcdef]
	KIO_3 - 0.5	1.57[a]	16.75[a]
	KIO_3 - 1	1.55[a]	15.10[b]
	KIO_3 / 2	1.39[b]	12.16[bcd]
	KIO_3 / 3	1.29[b]	9.29[bcde]

Means in the same column with different alphabet are significantly different ($p<0.05$) according to Duncan's Multiple range test

Discussion

Disease incidence and disease severity were significantly reduced with corresponding increase in yield by the application of iodine compounds at lower concentrations. The application of Potassium iodate at concentration of 0.5 mM had greatest positive effect on tomato. This is because it is more efficiently taken up by plant compared to potassium iodide (Lawson et. al., 2015). The application of potassium iodate at concentration of 1 mM and potassium iodide at 1 mM also had positive effect on tomato. Application of iodine compounds at higher concentration (potassium iodide at concentration of 5 mM) was toxic to the tomato plants as tomato plants treated with potassium iodide at concentration of 5 mM showed phytotoxicity symptoms such as leaf chlorosis, epinasty and visible wilting.

Iodine compound has been shown to be effective in controlling *Fusarium* wilt caused by the soil borne pathogen, it effectively controls Fusarium wilt of Basil (*Ocimum basilicum*) caused by *Fusarium oxysporum* f.sp. *basilici* (Adams et. al., 2003). It also significantly reduced the incidence and severity of *Fusarium* wilt of tomato caused by *Fusarium oxysporum* f.sp *lycopersici* at lower concentrations i.e potassium iodate at concentrations of 0.5 and 1 mM as well as potassium iodide at 1 mM. This confirmed earlier result that demonstrated that iodine compounds was potent on soil borne pathogens (Ohr et. al., 1996).

In tomato plants, a very low amount of iodine can stimulate the tangential growth and to some extent, improve the yield (Lehr et. al., 1958). However, at higher concentrations, iodine can be toxic leading to leaf damages, stunted growth, and death of the plant (Lehr et. al., 1958). It was also observed that the effect of the application of iodine on biomass was directly dependent .on the amount applied. Iodine compounds used in this study at lower concentrations (potassium iodate at concentrations of 0.5 mM, 1 mM and potassium iodide at concentration of 1 mM) promoted plant growth and increased fruit yield of tomato compared to the control plots and those treated with higher concentration (potassium iodide at concentration of 5 mM).

Application of potassium iodate at concentration of 0.5 mM significantly increased the yield of tomato plant in both accessions. There was also increase in the yield of tomato plants when iodine compound was applied at lower concentrations (potassium iodate at concentrations of 0.5 mM, 1 mM and potassium iodide at 1 mM), Tomato plants treated with potassium iodate at concentration of 0.5 mM produced better yield.

Conclusion

The study evaluated the responses of two tomato accessions grown in the screenhouse and on the field to iodine compounds. Lesser concentration of iodine compound application (potassium iodate at concentrations 0.5 mM and 1 mM as well as potassium iodide at 1 mM) had significant reduction on *Fusarium* wilt incidence and severity of tomato, which resulted in a significant yield increase. The protection of plants against pathogen using iodine compounds is a promising control strategy. One of the benefits of the use of iodine compounds should be a reduction of the use of fungicides which is of major concern to human health and environment.

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