Journal of Plant Sciences

ISSN 1816-4951

Academic
Journals Inc.

www.academicjournals.com

Journal of Plant Sciences 7 (3): 96-104, 2012
ISSN 1816-4951 / DOI: 10.3923/jps.2012.96.104

Mycotoxins and Non-fungicidal Control of Corn Grain Rotting Fungi

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ABSTRACT
To avoid fungicide risks, efficacy of *Allium sativum* was evaluated against corn grain rotting fungi. Mycotoxigenicity of tested fungi was also investigated using HPLC. All *Aspergillus* species were toxigenic except corn and popcorn isolates of *Aspergillus clavatus* as well as corn isolate of *Aspergillus terreus*. Highest Aflatoxin was produced by corn *Aspergillus flavus* and popcorn *Aspergillus flavus var. columnaris*. Meanwhile, three of eight *Fusarium* isolates were toxigenic and varied in the kind and amount of toxin produced. Although some Fusaria failed to produce any toxins, Popcorn isolate No. 8 of *Fusarium subglutinans* produced fumonisin, vomitoxin and zearalenone. Corn isolate of *Penicillium funiculosum* was produced more Patulin and less citreoviridin than corn isolate of *P. oxalicum*. Garlic juice was effectively inhibited the fungal growth at all concentrations used. All tested isolates were responded to garlic juice regardless of the concentration used. The most sensitive fungi to all garlic juice concentrations used were corn isolates of *A. flavus* and *Penicillium oxalicum*. They exhibited significant inhibitory effects of about 63.70 and 75.56%, respectively, at 1.25% concentration. Popcorn isolate of *F. subglutinans* was the most sensitive Fusaria to all concentrations used with maximum inhibition of about 81%. Efficacy of garlic juice against mycotoxin producing fungi suggests its possible use in minimizing the risk of mycotoxins as well as fungicides exposure.

Key words: HPLC, mycotoxins, seed-borne fungi, *Zea mays* L.

INTRODUCTION
Grain rotting *Aspergillus*, *Fusarium* and *Penicillium* fungi are generally invading corn (*Zea mays* L.) at pre-harvest period (Bigirwa *et al.*, 2007; Alakonya *et al.*, 2008). Field infection by these fungi may be continued and worsen throughout the post-harvest handling, marketing and storage periods (Bigirwa *et al.*, 2006; Jimoh and Kolapo, 2008). Other than yield losses, they are able to reduce grain quality polluting food and feedstuffs with hepatocarcinogens mycotoxins that harm animals and humans (Hussein and Brasel, 2001; Mokhles *et al.*, 2007; Iheshiulor *et al.*, 2011).

Chemical control of phytopathogens preventing rot development results in environmental pollution, health hazard and affects the natural ecological balance. Thus, early detection of grain rotting fungi and/or nonchemical fungicides application would result in more efficient control and may lead to improved storage (Onyeagba *et al.*, 2004; Yassin *et al.*, 2011).

Among several alternative strategies used to control phytopathogenic fungi and reduce mycotoxins in agricultural commodities; great success has been achieved using plant-derived products (Centeno *et al.*, 2010; Reddy *et al.*, 2010). Antifungal activity of many plant-derived products against wide range of phytopathogens had frequently been documented (Hasan *et al.*, 2005; Hadizadeh *et al*., 2009; Ikeura *et al*., 2011). Moreover; efficacy of some herbaceous and medicinal plants against corn seed borne mycoflora was proved (El-Samawaty *et al*., 2011; Kiran *et al*., 2010).

Among many plant substances generally used against seed-borne mycoflora; garlic is very promising and safer, particularly for food preservation (Haciseferogullari *et al*., 2005; Aqil *et al*., 2010). Garlic has abroad antimicrobial properties (Obagwu and Korsten, 2003; Irkin and Korukluoglu, 2007) and its activity against *Aspergillus* and *Penicillium* fungi and mycotoxin production had frequently been documented (Pereira *et al*., 2006; Ismaiel, 2008; Salim, 2011). The present study aimed to investigate antifungal activity of garlic juice against toxigenic fungi causing corn grain rot disease.

MATERIALS AND METHODS

This study was initiated in 2011; to investigate the efficacy of garlic juice against mycotoxin producing fungi isolated from corn grains.

Fungi: Twenty two isolates belonging to twelve species representing three fungal genera were used. Grain rotting *Aspergillus, Fusarium* and *Penicillium* fungal isolates were mainly recovered from commoditized corn and popcorn samples collected from different locations (markets) in Riyadh City of Saudi Arabia.

Garlic juice: Garlic juice was obtained by blending and homogenizing fresh garlic bulbs in enough quantity of distilled water (1 mL water/1 g garlic bulb v/w), for 5 min using a blender (Braun Combimax 700 Vital, Germany). Obtained juice was then filtered through one layer sheath clothes and used immediately or stored at 4°C until used (Ismaiel, 2008).

Aflatoxins: SMKY liquid medium (Diener and Davis, 1966) was used to examine aflatoxin productivity of *Aspergillus*. Aflatoxins were extracted from homogenized culture filtrates using methanol solution (80:20 methanol/isolate filtrates). Solvents were then evaporated under vacuum, dried residues containing aflatoxin were dissolved in 1 mL of methanol: acetic acid: water (1:1:3 v/v) solution and stored in dark vials. Aflatoxin analysis was performed on HPLC (Stroka *et al*., 2000).

***Penicillium* toxins:** Patulin and citreoviridin productivity were studied using HPLC. *Penicillium* isolates were aseptically cultured onto malt extract broth and incubated at 27±2°C for 7-10 days, after which mycotoxins were extracted using acetonitrile: water solution (5:95 v:v). Solvent was then evaporated under vacuum. Dried residues were dissolved in 1 mL of the same solution and then filtered through a 0.45 µm micro-filter prior to subject to HPLC analyses (O'Brien *et al*., 2006).

***Fusarium* toxins:** Isolates were grown on sterilized SMKY liquid medium for 10 days at 27±2°C. Fungal culture of each treatment was blended with 5 g sodium chloride and 100 mL of methanol: water (80:20) solution at a high speed for one min, then filtered through glass micro-fiber filter. Ten milliliter of the filtrate was diluted with 40 mL of wash buffer and filtered again through 1 µm micro-fiber filter. Fumonisin, zearalenone and vomitoxin concentration were performed on HPLC (Mazzani *et al*., 2001).

Antifungal activity of garlic juice: Crude solution of garlic juice were added to conical flasks containing 100 mL of sterilized PDA medium just before solidification to obtain concentrations of

1.25, 2.5, 5.0 and 10.0%. The supplemented media was immediately poured into 9 cm Petri plates. Five mm diameter plugs cutting from the margin of 7 days old fungal colonies were placed in the center of such plates (Benkeblia, 2004). Three replicate plates were used for each treatment and untreated plates were served as control. Cultures were incubated at 27±2°C and radial growth measured daily for 7-10 days. Obtained data were statistically analyzed.

Statistical analysis: Analysis of variance (ANOVA) was performed with the MSTAT-C statistical package, Michigan State Univ., USA). Least Significant Difference (LSD) was used to compare means.

RESULTS

Mycotoxin productivity: Aflatoxin assay revealed that most of *Aspergillus* were toxigenic and varied in the kind and amount of aflatoxins produced. Corn and popcorn isolates of *A. clavatus* as well as corn isolate of *A. terreus* were non toxigenic. B1 aflatoxin was generally the most dominant toxin. *A. flavus* isolate No. 2 and *Aspergillus flavus var. columnaris* isolate No. 8 were the highest producers of aflatoxin (Table 1).

Three of eight *Fusarium* isolates were toxigenic with varied production ability. While some isolates of *Fusarium proliferatum* and *Fusarium verticillioides* failed to produce any toxins, corn isolate of *F. proliferatum* (No. 3) produced both vomitoxins and zearalenone. On the other hand corn isolate of *F. verticillioides* (No. 4) produced only zearalenone. Popcorn isolate of *F. subglutinans* (No. 8) produced fumonisin, vomitoxin and zearalenone. However, *F. subglutinans* isolate No. 8 was the highest producer of fumonisin, *F. proliferatum* isolate No. 3 was the highest producer of vomitoxins and zearalenone (Table 2).

Corn isolate of *P. funiculosum* was produced more Patulin and less citreoviridin than corn isolate of *P. oxalicum*. Popcorn isolate of *Penicillium chermesinum* failed to produce any detectable amount of mycotoxins (Table 3). Moreover, while *P. funiculosum* isolate was the highest producer of patulin, *P. oxalicum* isolate was the highest producer of citreoviridin.

Antifungal activity of garlic juice: Statistical analysis indicated that garlic concentrations, fungal isolates and their interaction were highly significant sources of variation. Concentration was

Table 1: Aflatoxin productivity of corn and popcorn seed borne *Aspergillus* sp.

	Aflatoxin (ppb)				
Isolates	Host	B1	B2	G1	G2
A. clavatus	Corn	-	-	-	-
A. flavus	Corn	8.0	2.0	4.0	3.0
A. flavus	Corn	2.0	1.0	0.0	0.0
A. niger	Corn	3.0	-	2.0	2.0
A. terreus	Corn	-	-	-	-
A. clavatus	Popcorn	-	-	-	-
A. clavatus	Popcorn	-	-	-	-
A. f. var columnaris	Popcorn	8.0	6.0	3.0	6.0
A. flavus	Popcorn	6.0	2.0	1.0	3.0
A. fumigatus	Popcorn	2.0	3.0	1.0	2.0
A. niger	Popcorn	5.0	2.0	5.0	-

Table 2: Mycotoxin productivity of corn and popcorn seed borne *Fusarium* sp.

		Mycotoxin (ppb)		
Isolates	Host	Fumonisin	Zearalenone	Vomitoxin
F. proliferatum	Corn	-	-	-
F. proliferatum	Corn	-	-	-
F. proliferatum	Corn	-	5.4	7.4
F. verticillioides	Corn	-	3.3	-
F. verticillioides	Corn	-	-	-
F. verticillioides	Corn	-	-	-
F. subglutinans	Popcorn	-	-	-
F. subglutinans	Popcorn	9.7	1.4	6.3

Table 3: Mycotoxin productivity of corn and popcorn seed borne *Penicillium* sp.

		Mycotoxin (ppb)	
Isolates	Host	Patulin	Citreoviridin
P. funiculosum	Corn	31	20
P. oxalicum	Corn	21	25
P. chermesinum	Popcorn	-	-

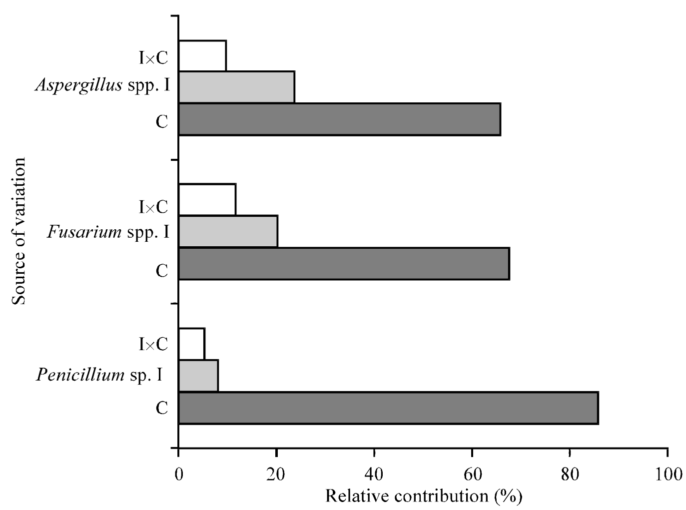

Fig. 1: Relative contribution of concentration (C), Isolates (I) and their interaction (I×C) to linear growth of corn and popcorn seed borne fungi

the most important as source of variation followed by isolates but the (I×C) interaction was the least in importance (Fig. 1).

Garlic juice was effectively inhibited the fungal growth at all concentrations and its activity was increased as concentration increased. Moreover, all tested isolates were responded to garlic juice regardless the concentration used. Corn isolates of *A. flavus* (Fig. 2) and *P. oxalicum* (Fig. 5) were the most sensitive isolates to all tested concentration of garlic juice. They exhibited significant inhibitory effects of 63.70 and 75.56%, respectively, at 1.25% concentration. Meanwhile, popcorn isolate of *A. fumigatus* was the most sensitive isolate to all concentrations by significant inhibition

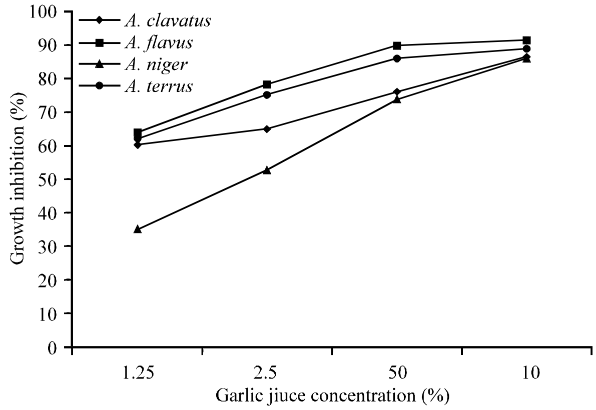

Fig. 2: Antifungal activity of garlic juice against corn seed borne *Aspergillus* species

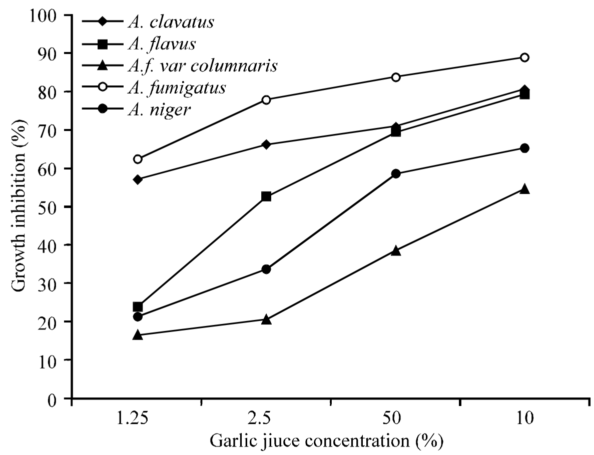

Fig. 3: Antifungal activity of garlic juice against popcorn seed borne *Aspergillus* species

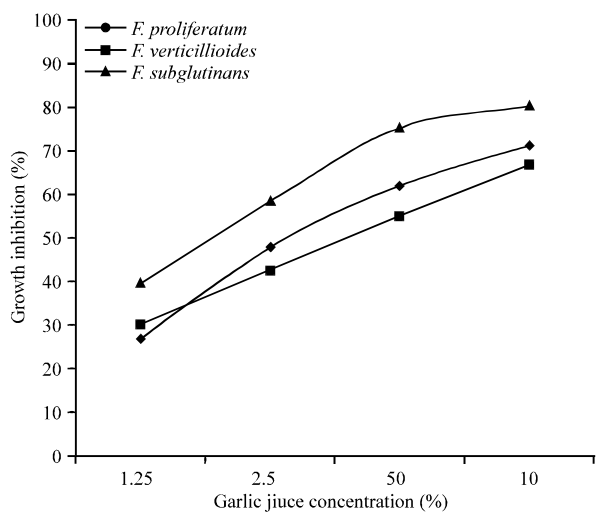

Fig. 4: Antifungal activity of garlic juice against corn and popcorn seed borne *Fusarium* species

of 62.22-88.89% (Fig. 3). On the other hand popcorn isolate of *F. subglutinans* was the most sensitive Fusaria to all concentrations with maximum inhibition of about 80.37% (Fig. 4).

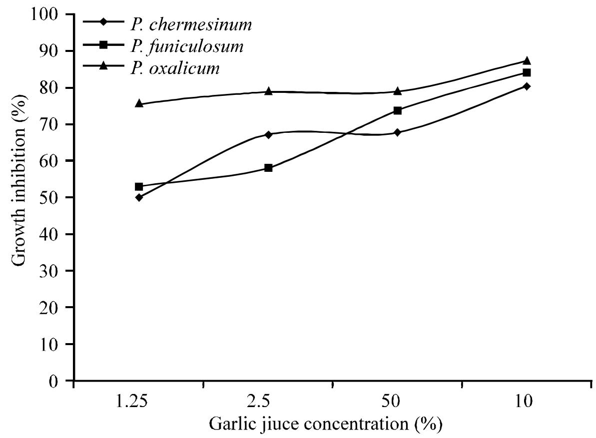

Fig. 5: Antifungal activity of garlic juice against corn and popcorn seed borne *Penicillium* species

DISCUSSION

Mycotoxigenicity of corn grain rotting fungi; *Aspergillus, Fusarium* and *Penicillium* have frequently been documented (Kumar *et al*., 2008; Trung *et al*., 2008; Amadi and Adeniyi, 2009). Aflatoxins; the most widespread toxins frequently produced by *Aspergillus* sp. isolated from corn grains (Muthomi *et al*., 2009; Youssef, 2009; Yassin *et al*., 2011). Fumonisins, vomitoxin and zearalenone were also produced by corn grain rotting Fusaria (Yazar and Omurtag, 2008; Makun, 2007). Production of patulin and citreoviridin by corn grain isolates of *P. funiculosum* and *P. oxalicum* were also demonstrated (Dombrink-Kurtzman and Blackburn, 2005; El-Samawaty *et al*., 2011). It was proved that phytopathogenic fungi may produce these toxins in culture media and in agricultural commodities as well as in food waste (Abramson *et al*., 2009).

In vitro screening of garlic juice activity against corn grain rotting fungi revealed that it was effectively inhibited mycelial growth of all tested fungi. This result was agreed with the finding of Afzal *et al*. (2010), who stated that *A. sativum* has a wide antifungal spectrum, reached about 60-82% inhibition in the growth of seed borne *Aspergillus* and *Penicillium* fungi. Efficacy of garlic in controlling toxigenic fungi had also proved by Salim (2011) who concluded that aqueous extracts of garlic could be used as a good natural food preservative against mycotoxigenic fungi. Many literatures worldwide also indicated that garlic had potential antifungal properties (Irkin and Korukluoglu, 2007; Rashid *et al*., 2010; Tagoe *et al*., 2011). Such antimycotic activity might be attributed to phytochemical properties of garlic plant (Obagwu and Korsten, 2003; Ogita *et al*., 2009). Garlic allicin however, decomposes into several effective antimicrobial compounds such as diallyl sulphide, diallyl disulphide, diallyl trisulphide, allyl methyl trisulphide, dithiins and ajoene (Harris *et al*., 2001; Jabar and Al-Mossawi, 2007).

It is concluded that efficacy of garlic juice against mycotoxin producing fungi suggests its possible use in minimizing the risk of mycotoxins as well as fungicides exposure. Meanwhile, water base usage of garlic juice provides an alternative of chemical solvents.

ACKNOWLEDGMENTS

This study was supported by the research Center, College of Science, King Saud University.

REFERENCES

Abramson, D., G. Lombaert, R.M. Clear, P. Sholberg, R. Trelka and E. Rosin, 2009. Production of patulin and citrinin by *Penicillium expansum* from British Columbia (Canada) apples. Mycotoxin Res., 25: 85-88.

Afzal, R., S.M. Mughal, M. Munir, S. Kishwar, R. Qureshi, M. Arshad and M.K. Laghari, 2010. Mycoflora associated with seeds of different sunflower cultivars and its management. Pak. J. Botany, 42: 435-445.

Alakonya, A.E., E.O. Monda and S. Ajanga, 2008. Effect of delayed harvesting on maize ear rot in Western Kenya. Am. Eurasian J. Agric. Environ. Sci., 4: 372-380.

Amadi, J.E. and D.O. Adeniyi, 2009. Mycotoxin production by fungi isolated from stored grains. Afr. J. Biotechnol., 8: 1219-1221.

Aqil, F., M. Zahin, I. Ahmed, M. Owais M.S.A. Khan, S.S. Bansal and S. Farooq, 2010. Antifungal Activity of Medical Plant Extracts and Phytocompounds: A Review. In: Combating Fungal Infections: Problem and Remedy, Ahmad, I., M. Owais and M. Shahid (Eds.). Springer-Verlag, Berlin Heidelberg, pp: 449-485.

Benkeblia, N., 2004. Antimicrobial activity of essential oil extracts of various onions (*Allium cepa*) and garlic (*Allium sativum*). LWT Food Sci. Technol., 37: 263-268.

Bigirwa, G., A.N. Kaaya, G. Sseruwu, E. Adipala and S. Okanya, 2007. Incidence and severity of maize ear rots and factors responsible for their occurrence in Uganda. J. Applied Sci., 7: 3780-3785.

Bigirwa, G., G. Sseruwu, A.N. Kaaya, E. Adipala and S. Okanya, 2006. Fungal microflora causing maize ear rots in uganda and associated aflatoxins. J. Boil. Sci., 6: 540-546.

Centeno, S., M.A. Calvo, C. Adelantado and S. Figueroa, 2010. Antifungal activity of extracts of *Rosmarinus officinalis* and *Thymus vulgaris* against *Aspergillus flavus* and *A. ochraceus*. Pak. J. Biol. Sci., 13: 452-455.

Diener, U.L. and N.D. Davis, 1966. Aflatoxin production by isolates *Aspergillus flavus*. Phytopathology, 56: 1390-1393.

Dombrink-Kurtzman, M.A. and J.A. Blackburn, 2005. Evaluation of several culture media for production of patulin by *Penicillium* species. Int. J. Food Microbiol., 98: 241-248.

El-Samawaty, A.M.A., M.A. Yassin, A. Bahkali, M.A. Moslem and K.A. Abd-Elsalam, 2011. Bio-fungal activity of aloe vera sap against mycotoxigenic seed-borne fungi. Fresenius Environ. Bull., 20: 1352-1359.

Haciseferogullari, H., M. Ozcan, F. Demir and S. Calisir, 2005. Some nutritional and technological properties of garlic (*Allium sativum* L.). J. Food Eng., 68: 463-469.

Hadizadeh, I., B. Peivastegan and M. Kolahi, 2009. Antifungal activity of nettle (*Urtica dioica* L.), colocynth (*Citrullus colocynthis* L. schrad), oleander (*Nerium oleander* L.) and konar (*Ziziphus spina-christi* L.) extracts on plants pathogenic fungi. Pak. J. Biol. Sci., 12: 58-63.

Harris, J.C., S.L. Cottrell, S. Plummer and D. Lloyd, 2001. Antimicrobial properties of *Allium sativum* (garlic). Applied Microbiol. Biotechnol., 57: 282-286.

Hasan, M.M., S.P. Chowdhury, Shahidul Alam, B. Hossain and M.S. Alam, 2005. Antifungal effects of plant extracts on seed-borne fungi of wheat seed regarding seed germination, Seedling health and vigour index. Pak. J. Biol. Sci., 8: 1284-1289.

Hussein, H.S. and J.M. Brasel, 2001. Toxicity, metabolism and impact of mycotoxins on humans and animals. Toxicology, 167: 101-134.

Iheshiulor, O.O.M., B.O. Esonu, O.K. Chuwuka, A.A. Omede, I.C. Okoli and I.P. Ogbuewu, 2011. Effects of mycotoxins in animal nutrition: A review. Asian J. Animal Sci., 5: 19-33.

Ikeura, H., N. Somsak, F. Kobayashi, S. Kanlayanarat and Y. Hayata, 2011. Application of selected plant extracts to inhibit growth of *Penicillium expansum* on Apple fruits. Plant Pathol. J., 10: 79-84.

Irkin, R. and M. Korukluoglu, 2007. Control of *Aspergillus niger* with garlic, onion and leek extracts. Afr. J. Biotechnol., 6: 384-387.

Ismaiel, A.A., 2008. Inhibitory effect of garlic extract of Penicillic acid production and growth of *Penicillium hirsutum*. Third Environment Conference, Faculty of Science, Zagazig University, pp: 45-58.

Jabar, M.A. and A. Al-Mossawi, 2007. Susceptibility of some multiple resistant bacteria to garlic extract. Afr. J. Biotechnol. 6: 771-776.

Jimoh, K.O. and A.L. Kolapo, 2008. Mycoflora and aflatoxin production in market samples of some selected Nigerian foodstuffs. Res. J. Microbiol., 3: 169-174.

Kiran, B., V. Lalitha and K.A. Raveesha, 2010. Screening of seven medicinal plants for antifungal activity against seed borne fungi of maize seed. Afr. J. Basic Appl. Sci., 2: 99-103.

Kumar, V., M.S. Basu and T.P. Rajendran, 2008. Mycotoxin research and mycoflora in some commercially important agricultural commodities. Crop Prot., 27: 891-905.

Makun, H.A., 2007. Studies on mycoflora and mycotoxins contaminating guinea corn and rice in Niger State, Nigeria. Ph.D Thesis, Submitted to the Department of Biochemistry, Federal University of Technology, Minna, Niger. pp. 1-219.

Mazzani, C., O. Borges, O. Luzon, V. Barrientos and P. Quijada, 2001. Occurrence of *Fusarium moniliforme* and fumonisins in kernels of maize hybrids in venezuela. Brazilian J. Microbiol., 32: 345-349.

Mokhles, M., M.A. Abd El Wahhab, M. Tawfik, W. Ezzat, K. Gamil and M. Ibrahim, 2007. Detection of aflatoxin among hepatocellular carcinoma patients in Egypt. Pak. J. Biol. Sci., 10: 1422-1429.

Muthomi, J.W., L.N. Njenga, J.K. Gathumbi and G.N. Chemining`wa, 2009. The occurrence of aflatoxins in maize and distribution of mycotoxin-producing fungi in Eastern Kenya. Plant Pathol. J., 8: 113-119.

O`Brien, M., K.F. Nielsen, P. O`Kiely, P.D. Forristal, H.T. Fuller and J.C. Frisvad, 2006. Mycotoxins and other secondary metabolites produced *in vitro* by *Penicillium paneum* frisvad and *Penicillium roqueforti* thom isolated from baled grass silage in Ireland. J. Agric. Food Chem., 54: 9268-9276.

Obagwu, J. and L. Korsten, 2003. Control of citrus green and blue molds with garlic extracts. Eur. J. Plant Pathol., 109: 221-225.

Ogita, A., K. Fujita and T. Tanaka, 2009. Enhancement of the fungicidal activity of amphotericin B by allicin: Effects on intracellular ergosterol trafficking. Planta Med., 75: 222-226.

Onyeagba, R.A., O.C. Ugbogu, C.U. Okeke and O. Iroakasi, 2004. Studies on the antimicrobial effects of garlic (*Allium sativum* Linn), ginger (*Zingiber officinale* Roscoe) and lime (*Citrus aurantifolia* Linn). Afr. J. Biotechnol., 3: 552-554.

Pereira, M.C., S.M. Chalfoun, C.J. Pimenta, C.L. Angelico and W.P. Maciel, 2006. Spices, fungi mycelial development and ochratoxin A production. Sci. Res. Essays, 1: 38-42.

Rashid, M.M., A.B.M. Ruhul Amin and F. Rahman, 2010. Determination of effective dose of garlic for controlling seed borne fungal disease of tomato. J. Yeast Fungal Res., 1: 183-187.

Reddy, K.R.N., S.B. Nurdijati and B. Salleh, 2010. An overview of plant-derived products on control of mycotoxigenic fungi and mycotoxins. Asian J. Plant Sci., 9: 126-133.

Salim, A.B., 2011. Effect of some plant extracts on fungal and aflatoxin production. Int. J. Acad. Res., 3: 116-120.

Stroka, J., E. Anklam, U. Jorissen and J. Gilbert, 2000. Immuno-affinity column clean-up with liquid chromatography post column bromination for determination of aflatoxins in peanut butter, pistachio paste, fig paste and paprika powder: Collaborative study. J. Assoc. Anal. Commun. Interac., 83: 320-340.

Tagoe, D., S. Baidoo, I. Dadzie, V. Kangah and H. Nyarko, 2011. A comparison of the antimicrobial (Antifungal) properties of onion (*Allium* cepa), Ginger (*Zingiber officinal*) and garlic (*Allium sativum*) on *Aspergillus flavus*, *Aspergillus niger* and *Cladosporium herbarum* Using organic and water base extraction methods. Res. J. Med. Plant, 5: 281-287.

Trung, T.S., C. Tabuc, S. Bailly, A. Querin, P. Guerre and J.D. Bailly, 2008. Fungal mycoflora and contamination of maize from Vietnam with aflatoxin B1 and fumonisin B1. World Mycotoxin J., 1: 87-94.

Yassin, M.A., A.M.A. El-Samawaty, M. Moslem, A. Bahkali and K.A. Abd-Elsalam, 2011. Fungal biota and occurrence of aflatoxigenic *Aspergillus* in postharvest corn grains. Fresenius Environ. Bull., 20: 903-909.

Yazar, S. and G.Z. Omurtag, 2008. Fumonisins, trichothecenes and zearalenone in cereals. Int. J. Mol. Sci., 9: 2062-2090.

Youssef, M.S., 2009. Natural occurrence of mycotoxins and mycotoxigenic fungi on Libyan corn with special reference to mycotoxin control. Res. J. Toxins, 1: 8-22.