The impact of conservation agriculture on maize ear rots and resultant mycotoxin production in commercial and smallholder farming systems

MTM 19/03

Dr. Belinda Janse van Rensburg

BelindaJ@arc.agric.za

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Background

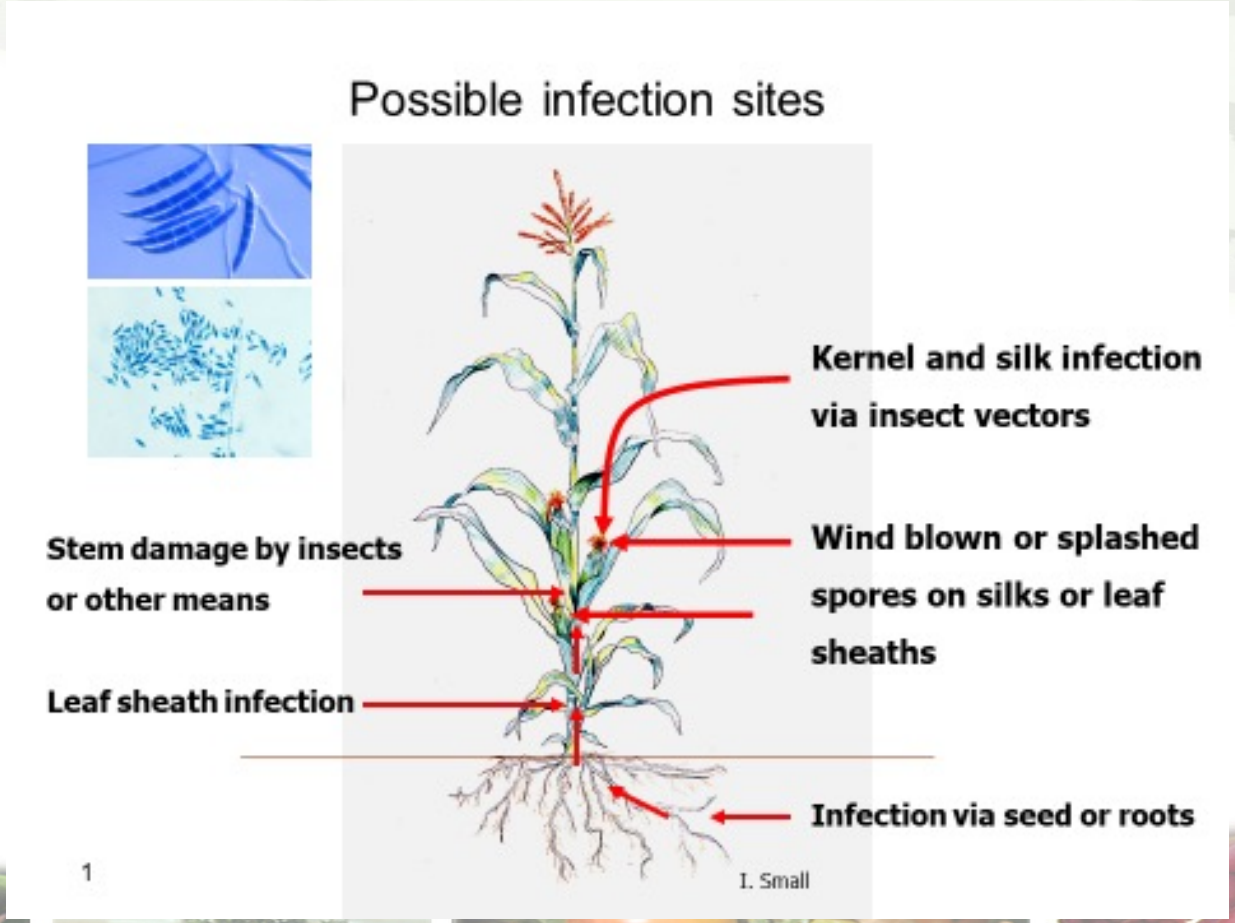
- Does an increase in residue cause an increase in disease and mycotoxins?
- Crop rotation is crucial, however maize residues take longer to decompose

  - harbor Fusarium and other ear rot pathogens much longer
- 2019/20 – 2022/23

Aim

- To determine the effect of agricultural cropping systems on maize ear rot infection and mycotoxin contamination in diverse production areas (commercial and smallholder farmers)

Where does the fungi come from that produce mycotoxins?



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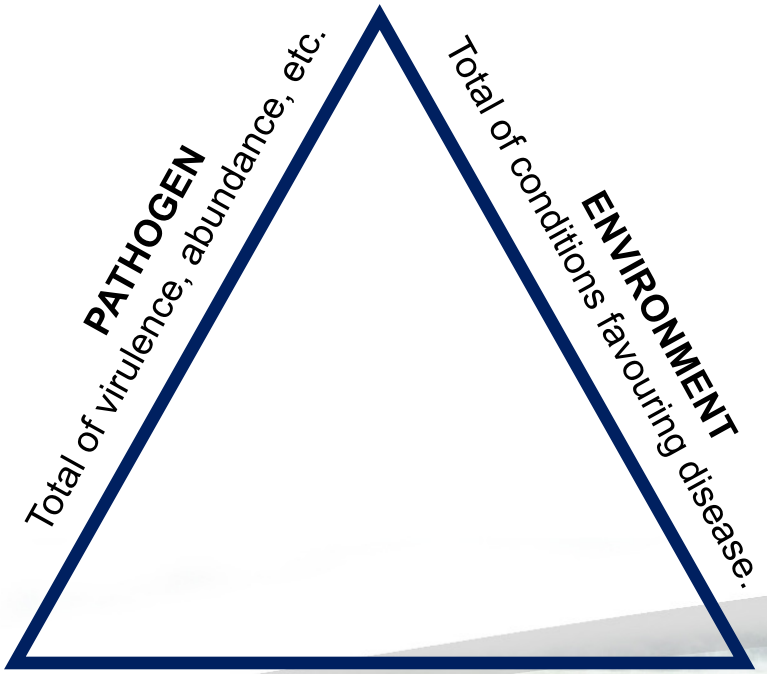
The Disease Triangle



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Fusarium verticillioides / F. proliferatum

-FB_1, FB_2, FB_3

-Fungus can present in the seed

-Infect roots, stalks, ears (susceptible from flowering stage)

-Hot, dry weather conducive for infection (28-32 °C)

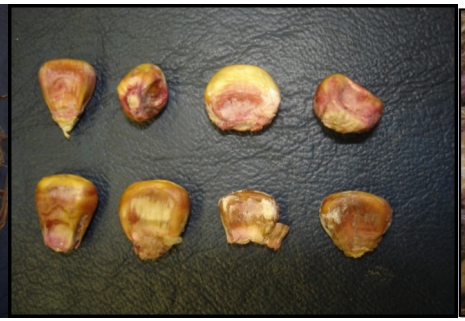
Fusarium graminearum spp. complex

-DON, NIV, ZEA

-Fungus can present in the seed

-Infect roots, stalks, ears (susceptible from flowering stage)

-Hot, wet weather conducive for infection (25-32 °C)



Stenocarpella maydis

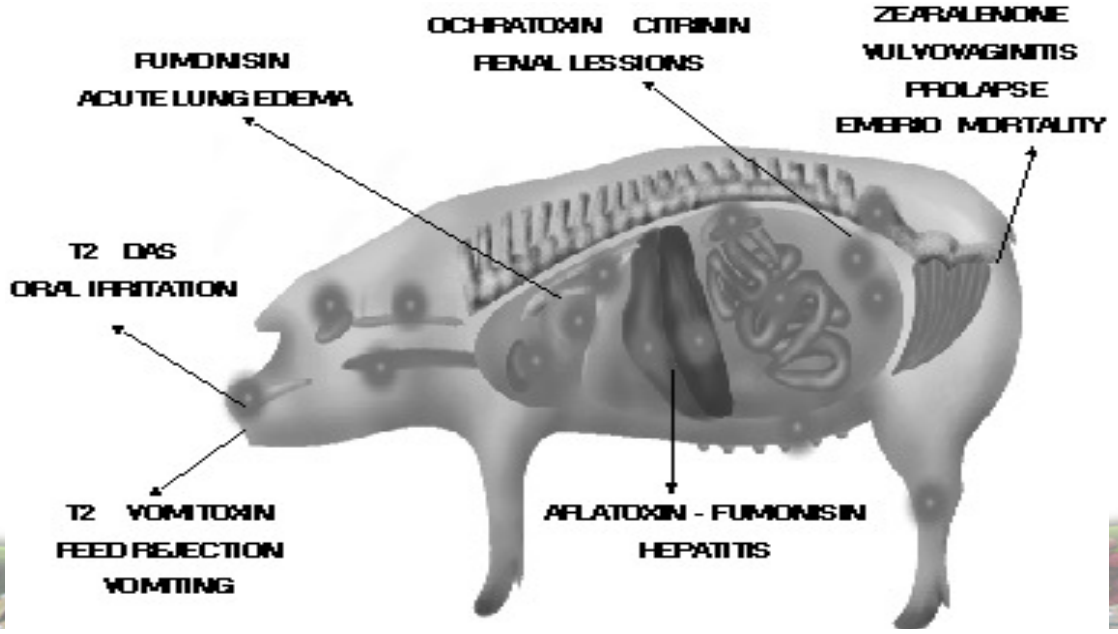
-Diplodiatoxin, Dipmatol

- *diplodiosis, a neuromycotoxicosis of cattle and sheep*
- *Maize is the only host*
- *Start at the base of the maize ear, grow upward*
- *Late season rains, "skelm" Diplodia*

M.G. Masango, B.C. Flett, C.E. Ellis and C.J. Botha. *Stenocarpella maydis* and its toxic metabolites: a South African perspective on diplodiosis. World Mycotoxin Journal, 2015; 8 (3): 341-350 Wageningen Academic Publishers.

Why must we manage mycotoxins?

- Affect the entire food and feed production chain.
- Reduction of marketable grain, increased cost of drying, decreased weight gain in animal feeding, fertility problems, and increased costs for animal and human health.
- Restrict markets (for developing countries)



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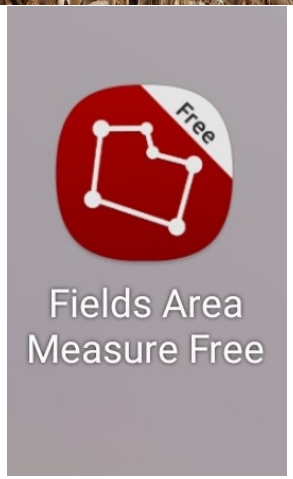
Materials and Methods

- **Commercial farmers (2019/20 – 2022/23)**
- Ottosdal, Kroonstad, Makwassie, Reitz
- 56 samples collected before harvest
  - different CA farming practices
- GPS – Fields area measure app

- **Smallholder farmers (2019/20 – 2022/23)**
- Bergville, Southern KZN, Midlands
- 77 samples collected before harvest
  - different CA farming practices

- individual samples sent to SAGL for multi – mycotoxin analyses
- Milled samples – DNA extractions, qPCR



Results – Commercial farmers

Table 1: Experimental design including maize monoculture, crop rotations, two different row widths and plant densities, repeated three times over a three-year time period (Ottosdal trial only).

	2018/19	2019/20	2020/21	2021/22
Block 1	Maize 50* Maize 90	Maize 50 Maize 90	Maize 50 Maize 90	Maize 50 Maize 90
	Maize 50 Maize 90	Sunflower	Cover crop	Maize 50 Maize 90
	Cover crop	Maize 50 Maize 90	Sunflower	Cover crop
Block 2	Maize 50 Maize 90	Maize 50 Maize 90	Maize 50 Maize 90	Maize 50 Maize 90
	Maize 50 Maize 90	Sunflower	Cover crop	Maize 50 Maize 90
	Cover crop	Maize 50 Maize 90	Sunflower	Cover crop
Block 3	Maize 50 Maize 90	Maize 50 Maize 90	Maize 50 Maize 90	Maize 50 Maize 90
	Maize 50 Maize 90	Sunflower	Cover crop	Maize 50 Maize 90
	Cover crop	Maize 50 Maize 90	Sunflower	Cover crop

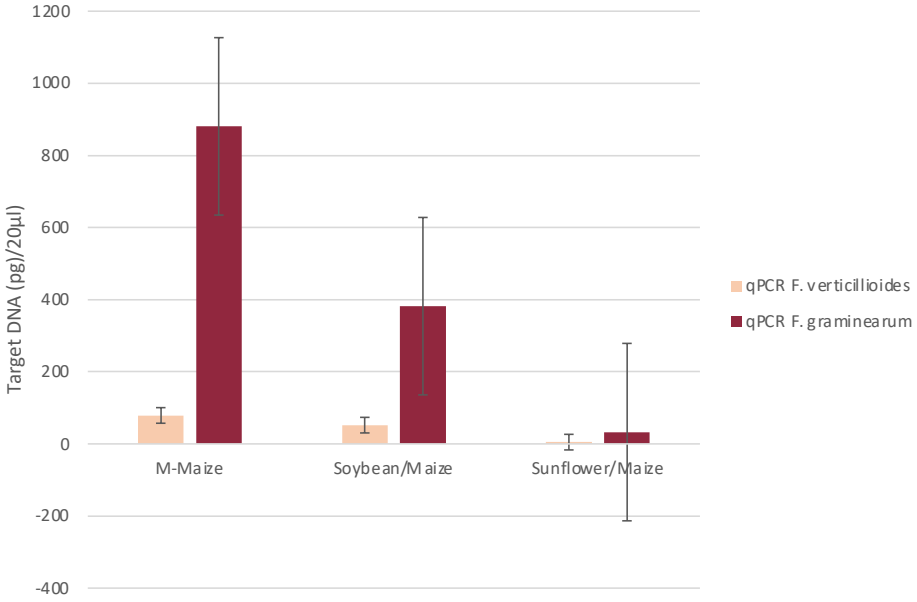
Maize 50 = row width 50 cm and plant density = 40 000ha^{-1}

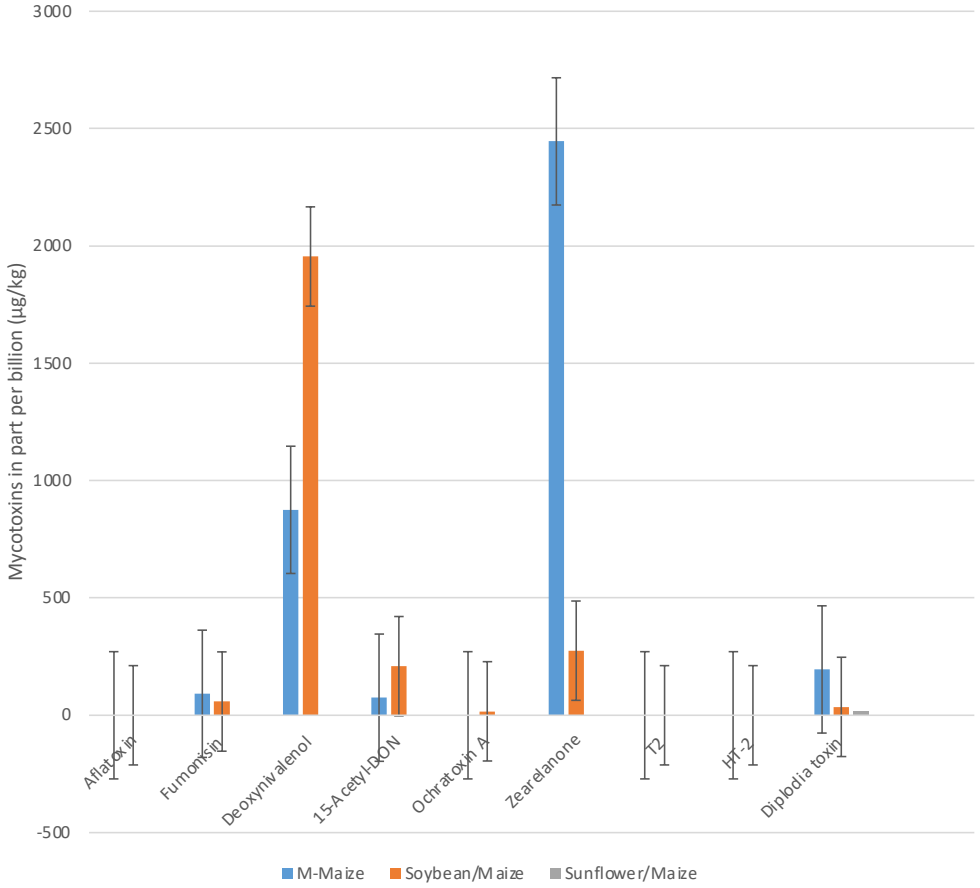
Locality	Crop system	Cultivation	Season	qPCR F. verticillioides (pg)/20µl	qPCR F. graminearum (pg)/20µl	Aflatoxin ppb (µg/kg)	Fumonisin ppb (µg/kg)	Deoxynivalenol ppb (µg/kg)	15-AcetyI-DON ppb (µg/kg)	Ochratoxin A ppb (µg/kg)	Zearelanone ppb (µg/kg)	T2 ppb (µg/kg)	HT-2 ppb (µg/kg)	Diplodia toxin ppb (µg/kg)
Kroonstad (northern Free State Province)	Fallow		2018/2019											
	M-Maize (control)	Rip on row Sandy soil	2019/2020	40	430	ND	ND	410	103	ND	ND	ND	ND	ND
	M-Maize (control)		2020/2021	45	1364	ND	101	1604	139	ND	54	ND	ND	ND
	M-Maize (control)		2021/2022	4	7.36	ND	24	211	ND	ND	ND	ND	ND	247
Kroonstad	Sorghum as cover crop		2018/2019											
	Maize	Rip on row Sandy soil	2019/2020	53	375	ND	27	509	<LOQ	ND	31	ND	ND	ND
	Maize		2020/2021	22	99	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Maize		2021/2022	58	56.9	ND	ND	ND	ND	ND	ND	ND	ND	90
Kroonstad	Intercrop, soybeans and maize	Rip on row Sandy soil	2020/2021	89	78	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Intercrop, soybeans and maize		2021/2022	16	148	ND	ND	844	157	ND	ND	ND	ND	ND
Kroonstad mean values				40.87	319.78	0	19	447.25	49.88	0	10.62	0	0	42.13

Locality	Crop system	Cultivation	Season	qPCR F. verticillioides (pg)/20µl	qPCR F. graminearum (pg)/20µl	Aflatoxin ppb (µg/kg)	Fumonisin ppb (µg/kg)	Deoxynivalenol ppb (µg/kg)	15-Acetyl-DON ppb (µg/kg)	Ochratoxin A ppb (µg/kg)	Zearelanone ppb (µg/kg)	T2 ppb (µg/kg)	HT-2 ppb (µg/kg)	Diplodia toxin ppb (µg/kg)
Makwassie (North-West Province)	M-maize (control)	Rip on row Sandy soil	2019/2020	43	931	ND	ND	1020	119	ND	ND	ND	ND	ND
	M-maize (control)		2020/2021	27	408	ND	ND	138	ND	ND	ND	ND	ND	ND
Makwassie	Fallow	Rip on row	2018/2019											
	Maize	Sandy soil	2019/2020	544	6455	ND	682	7144	345	ND	26193	ND	ND	ND
	Maize		2020/2021	25	365	ND	307	ND	ND	ND	ND	ND	ND	ND
	Maize		2021/2022	61	51	ND	55	ND	ND	ND	ND	ND	ND	303
Makwassie	Ground-nuts	Rip on row	2018/2019											
	Maize	Sandy soil	2019/2020	101	881	ND	ND	9619	1042	ND	71	ND	ND	ND
	Soya		2020/2021											
	Maize		2021/2022	100		ND	373	2035	266	ND	37	ND	ND	84
Makwassie	Sunflower	Rip on row	2019/2020											
	Maize	Sandy soil	2020/2021	5	27	ND	ND	ND	ND	ND	ND	ND	ND	ND
Makwassie mean values				113.25	1302	0	177.13	2494.5	221.5	0	3287.63	0	0	48.38

Locality	Crop system	Cultivation	Season	qPCR F. verticillioides (pg)/20µl	qPCR F. graminearum (pg)/20µl	Aflatoxin ppb (µg/kg)	Fumonisin ppb (µg/kg)	Deoxynivalenol ppb (µg/kg)	15-Acetyl-DON ppb (µg/kg)	Ochratoxin A ppb (µg/kg)	Zearelanone ppb (µg/kg)	T2 ppb (µg/kg)	HT-2 ppb (µg/kg)	Diplodia toxin ppb (µg/kg)
Reitz (eastern Free State Province)	**M-Maize M-Maize (control)**	**No-till Hattingh 50cm rw**	**2018/2019 2019/2020**	**45.3**	**458**	**ND**	**22**	**736**	**119**	**ND**	**34**	**ND**	**ND**	**ND**
Reitz	Mixed seed for cattle grazing Maize Maize	No-till Hattingh 50 cm rw	2018/2019 2019/2020 2020/2021	70 2.15	129 51	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND 93
Reitz	Sunflower Maize Maize	No-till Hattingh 50 cm rw	2018/2019 2019/2020 2020/2021 2021/2022	ND 14 0.56	64.4 30.2 9.15	ND ND ND	ND ND ND	ND ND ND	ND ND ND	ND ND ND	ND ND ND	ND ND ND	ND ND ND	<LOQ ND 72
Reitz	Soya Maize Maize	No-till Hattingh 50 cm rw	2019/2020 2020/2021 2021/2022	1.98 1.96	2.54 4.28	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND
Reitz mean values				16.99	93.57	0	2.75	92	14.87	0	4.25	0	0	20.63

Mean *F. verticillioides* and *F. graminearum* levels (pg/20µl) measured from maize grain from three different cropping systems over a three year period





Mean mycotoxin (ppb) measured from maize grain from different cropping systems over a three year period

Results – Smallholder farmers

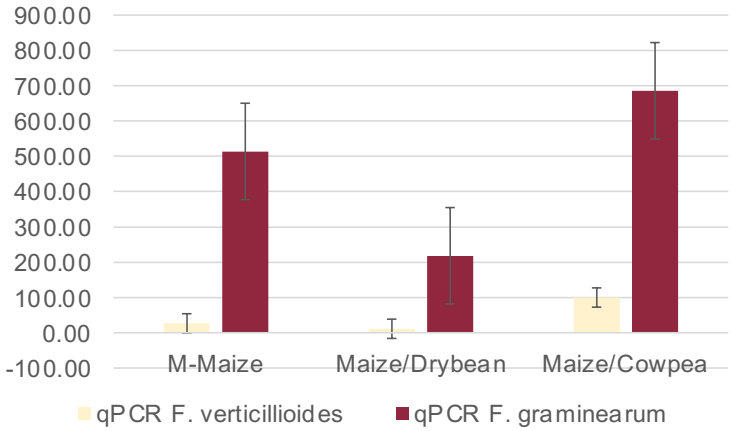
Farmer / Locality	Crop system	Cultivation	Season	qPCR *F. verticillioides* (pg)/20µl	qPCR *F. graminearum* (pg)/20µl	Aflatoxin ppb (µg/kg)	Fumonisin ppb (µg/kg)	Deoxynivalenol ppb (µg/kg)	15-Acetyl-DON ppb (µg/kg)	Ochratoxin A ppb (µg/kg)	Zearelanone ppb (µg/kg)	T2 ppb (µg/kg)	HT-2 ppb (µg/kg)	Diplodia toxin ppb (µg/kg)
Babhekele Nene (Bergville - Mayizekane)	M-Maize (control)	No-till	2019/2020 2020/2021 2021/2022	ND 78 125	1126 358 1987	ND ND ND	ND 168 ND	ND ND ND	ND ND ND	ND ND ND	354 25 **18517**	ND ND ND	ND ND ND	80 ND ND
Babhekele Nene	Maize – Bean intercrop	No-till	2019/2020 2020/2021 2021/2022	7.4 12.3 9.89	350 256 1860	ND ND ND	752 117 ND	ND 593 ND	ND ND ND	ND ND ND	85 **6110** **6823**	ND ND ND	ND ND ND	ND ND ND
Babhekele Nene	Maize – Cowpea intercrop	No-till	2019/2020 2020/2021	70.5 65	2386 2468	ND ND	801 ND	ND **1645**	ND 198	ND ND	**4294** **2902**	ND ND	ND ND	ND ND
Fikile Maphumolo (Bergville -Mayizekane)	Maize-Cowpea intercrop	No-till	2019/2020	5	82.7	ND	ND	ND	ND	ND	**976**	ND	ND	ND
Fikile Maphumolo	M-Maize (control)	No-till	2019/2020	128	38	ND	**2266**	ND	ND	**ND**	21	ND	ND	ND
Nomusa Shandu (Bergville -Mayizekane)	Maize – Cowpea intercrop	No-till	2019/2020 2020/2021	779 45	1152 687	ND ND	ND ND	ND 134	ND ND	ND ND	**587** ND	1409 ND	1446 ND	ND ND
Nomusa Shandu	M-Maize (control)	No-till	2019/2020 2020/2021	24 2.9	2698 987	ND ND	**6896** ND	ND **2533**	ND ND	ND ND	63 117	ND ND	ND ND	ND 1338
Nomusa Shandu	Maize-Beans intercrop	No-till	2019/2020 2020/2021	25 12	146 569	ND ND	105 1309	ND ND	105 ND	ND ND	29 ND	ND ND	ND ND	ND ND
Simephi Hlatswhayo (Bergville - Eqeleni)	M-Maize (control)	No-till	2019/2020	3	96	ND	ND	798	208	ND	144	ND	ND	ND

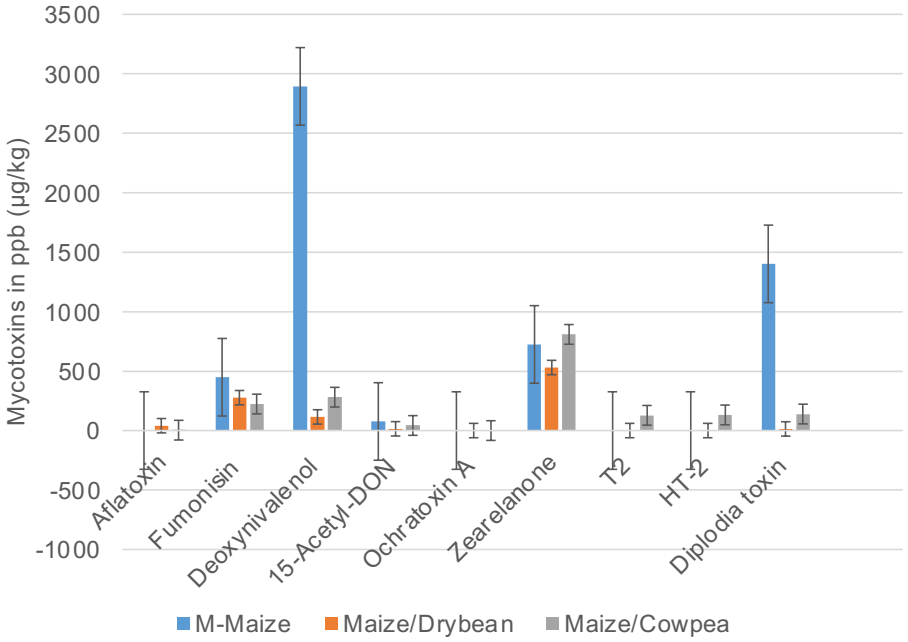
Simephi Hlatswhayo	M-Maize (control)	No-till	2019/2020	1.4	3	ND	ND	240	<LOQ	ND	ND	ND	ND	ND
Simephi Hlatswhayo	M-Maize (control)	No-till	2019/2020	1.9	17.6	ND	ND	530	168	ND	<LOQ	ND	ND	ND
Simephi Hlatswhayo	M-Maize (control)	No-till	2019/2020	ND	231	ND	ND	613	144	ND	105	ND	ND	ND
Nthombakhe Zikode (Bergville - Eqeleni)	M-Maize (control)	No-till	2020/2021	45.9	6987	ND	80	**9546**	438	ND	**6703**	ND	ND	ND
Nthombakhe Zikode	Maize - Beans intercrop	No-till	2020/2021	2.36	215	ND	137	ND	ND	ND	ND	ND	ND	ND
Nthombakhe Zikode	Maize - Cowpea intercrop	No-till	2020/2021	1.26	458	ND	1650	ND	ND	ND	ND	ND	ND	ND
Neliswe Msele (Bergville - Stulwane)	Maize - Beans intercrop	No-till	2019/2020 2020/2021 2021/2022	35 22 88	61 36 22	ND ND ND	ND ND ND	ND ND 695	ND ND 190	ND ND ND	29 ND 99	ND ND ND	ND ND ND	ND ND 66
Neliswe Msele	Maize - Cowpea intercrop	No-till	2019/2020 2020/2021	51.2 7.9	221 53	ND ND	ND ND	400 907	<LOQ 271	ND ND	134 ND	ND ND	ND ND	ND 1526
Neliswe Msele	M-Maize (control)	No-till	2019/2020 2020/2021 2021/2022	81 25 31.5	90 254 9.70	ND ND ND	ND ND ND	444 387 657	180 ND 291	ND ND ND	78 100 23	ND ND ND	ND ND ND	ND ND **2847**
Neliswe Msele	Maize - Cowpea intercrop	No-till	2019/2020 2020/2021	48 25	17 18	ND 36	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND
Neliswe Msele	M-Maize (control)	No-till	2019/2020 2020/2021 2021/2022	12 2.5 22	602 879 21	ND ND ND	615 1600 ND	**1665** ND ND	223 ND ND	ND ND ND	49 ND ND	ND ND ND	ND ND ND	ND 647 393
Phumelele Hlongwane (Bergville - Ezibomvini)	Maize (control)	No-till	2019/2020 2020/2021 2021/2022	7.9 5.89 1.35	21.4 22 9.25	ND ND ND	157 24 ND	420 ND 206	114 ND 217	ND ND ND	<LOQ 226 ND	ND ND ND	ND ND ND	ND **15433** ND

Phumelele Hlongwane	Maize - Beans intercrop	No-till	2019/2020 2020/2021 2021/2022	4.4 5.4 0.83	16.7 238 2.88	ND ND ND	ND 302 ND	ND ND ND	ND ND ND	ND ND ND	ND ND ND	ND ND ND	ND ND ND	ND ND ND
Phumelele Hlongwane	Maize - Beans intercrop	No-till	2019/2020 2020/2021 2021/2022	ND 2.3 1.31	595 25 11.7	373 ND ND	127 24 ND	ND ND 129	ND ND ND	ND ND ND	ND ND ND	ND ND ND	ND ND ND	ND ND ND
Phumelele Hlongwane	Maize (control)	No-till	2019/2020 2020/2021	17 125	85 698	ND ND	234 **5750**	**1950** **1623**	177 159	ND ND	30 31	ND ND	ND ND	ND 842
Phumelele Hlongwane	Maize - cover crop	No-till	2019/2020	34	100	ND	240	**1418**	518	ND	107	ND	ND	ND
Sibongile Mpulo (Bergville - Vimbukhalo)	Maize (control)	No-till	2019/2020 2020/2021	1.3	ND	ND ND	ND ND	ND ND	ND ND	ND ND	27 ND	ND ND	ND ND	ND **12798**
Sibongile Mpulo	Maize (control)	No-till	2019/2020 2020/2021	35	ND	ND ND	23 41	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND
Sibongile Mpulo	Maize	No-till	2019/2020	3.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sibongile Mpulo	Maize - Cowpea intercrop	No-till	2019/2020	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sibongile Mpulo	Maize - Beans intercrop	No-till	2019/2020 2020/2021	1.4 ND	2.4 ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND
Sibongile Mpulo	Maize - Beans intercrop	No-till	2019/2020 2020/2021	10.2 2.8	78 89	ND ND	ND ND	399 826	<LOQ ND	ND ND	ND 1099	ND ND	ND ND	ND ND
Letta Ngubo (SKZN - Springvalley)	Maize - Beans intercrop	No-till	2019/2020 2020/2021	4.6 ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND
Letta Ngubo	M-Maize (control)	No-till	2019/2020 2020/2021	134	ND	ND ND	81 ND	<LOQ **2467**	ND ND	ND ND	ND 1646	ND ND	ND ND	ND ND
Zweni Ndaba (Bergville - Emabunzini)	Maize - Beans intercrop	No-till	2019/2020	39	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lethiwe Zimba (Ndunwana)	Maize	No-till	2019/2020	4.8	ND	ND	ND	ND	ND	ND	56	ND	ND	ND

CD Xaba (SKZN – Madzikane)	Maize from plots pooled together	No-till	2019/2020 2020/2021 2021/2022	9.2 ND ND	307 ND 30	ND ND ND	ND ND ND	**2050** ND 192	316 ND ND	ND ND ND	53 ND ND	ND ND ND	ND ND ND	ND 525 ND
CD Xaba	M-Maize (control)	No-till	2019/2020 2020/2021 2021/2022	47.7 ND 2.03	ND 30 326	ND ND ND	ND ND ND	ND ND 1703	ND ND 205	ND ND ND	ND 65 ND	ND ND ND	ND ND ND	ND 221 4986
CD Xaba	Maize - Beans intercrop	No-till	2020/2021 2021/2022	12.9 4.18	697 44.2	ND ND	3942 ND	151 302	ND 100	ND ND	37 ND	ND ND	ND ND	ND 95
Rita Ngobese (Midlands - Gobizembe)	Maize - Beans intercrop	No-till	2020/2021	ND	211	724	ND	ND	ND	ND	ND	ND	ND	118
Martina Xulu (Eswathini)	M-Maize (control)	No-till	2020/2021 2021/2022	ND 4	54 134	ND ND	ND ND	130 ND	ND ND	ND ND	ND 367	ND ND	ND ND	ND 144
Martina Xulu	M-Maize (control)	No-till	2020/2021 2021/2022	ND ND	111 798	ND ND	ND ND	549 **1146**	ND 215	ND ND	113 55	ND ND	ND ND	**15736** 61
Martina Xulu	Maize - Beans intercrop	No-till	2020/2021 2021/2022	ND ND	365 ND	ND ND	644 ND	ND ND	ND ND	ND ND	ND ND	ND ND	ND ND	89 ND

Mean *F. verticillioides* and *F. graminearum* levels (pg/20µl) measured from maize grain from three different cropping systems over a three year period.





Mean mycotoxins (ppb) measured from maize grain from different cropping systems over a three year period.

Discussion

- Mycotoxin concentrations varied from one season to another
- Monoculture maize systems showed higher levels of fungi and mycotoxins
- Visual correlation observed between amount of fungi and specific mycotoxins associated with it
- Soybean and/or stubble may be a host for the *F. graminearum* spp. complex (commercial farmers)

-Sunflower is a suitable rotation crop

- Maize/cowpea intercrop systems had higher *F. verticillioides* and *F. graminearum* infections compared to

monoculture maize systems

- Cowpea produce minimal crop residues, but may be a host for the *F. graminearum* spp. complex

(smallholder farmers)

-Dry beans is a suitable rotation crop

- Diplodiatoxin measured for the first time in SA – monoculture maize – smallholder farmers