The effect of *Fusarium* spp. on germination and establishment of super-sweet corn cv. Illini Gold

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Abstract

The quality of two captan treated seed lots of shrunken-2 super-sweet corn (*Zea mays* L.) cv. Illini Gold was assessed in the laboratory. Although the lots differed in thousand seed weight, they had similar germination (86-88%). Both seed lots were infected with the pathogen *Fusarium subglutinans*, with from 60-82% of the seeds infected. Field emergence of these two seed lots averaged 63% for an October sowing, 70% for a November sowing, and 78% for a December sowing in Manawatu. Stand establishment (plants/m^2 as a percentage of seeds sown) averaged 58% for the October sowing, 65% for the November sowing, but only 35% for the December sowing because of seedling losses caused by *Fusarium*, particularly *F. graminearum*. Seeds harvested from this time-of-sowing trial were infected with *F. subglutinans, F. graminearum, F. poae* and unidentified *Fusarium* spp., the percentage of infected seeds ranging from 67 to 90% depending on harvest date. Storage of the original seed lots at 5°C for 14 months reduced *F. subglutinans* levels to under 20%, and when these two stored seed lots were field sown, emergence was 82 and 90%. These results emphasise the importance of effective seed treatment for control of seed- and soil-borne *Fusarium* spp. when growing super-sweet corn.

Additional key words: Fusarium graminearum, F. subglutinans, *field emergence, seedling death.*

Introduction

Fresh market sweet corn earns around NZ$6 million annually (Dept of Statistics 1992) with the market dominated by super-sweet corn genotypes. These have rapidly gained popularity because of their high sugar levels. The incorporation of high sugar endosperm mutant genes, such as sh2, alters the carbohydrate synthesis pathway in the endosperm, particularly inhibiting formation of water insoluble polysaccharides, and thus raising the sugar levels (Gonzales *et al.*, 1976; Ferguson *et al.*, 1978). Starch synthesis is usually around 25-30% of that of normal maize (Bewley and Black, 1978).

These features of super-sweet corn which enhance eating quality and acceptability pose some seed related production problems, particularly because of poor seed quality (Juvic *et al.*, 1993). These are:

1. The concentrated sucrose solution in endosperm resists drying (Wilson and Trawatha, 1991), which in turn interferes with the completion of seed maturation (Churchill and Andrew, 1983).
2. Waiting for seed dry down on plants results in late harvest, so that seeds are subjected to weathering and/or pathogen damage (Mashauri, 1993).
3. If seed is harvested at high moisture content, drying is necessary, and seeds can be subjected to both physical and physiological damage (Herter and Burris, 1989).
4. Low starch levels result in severely collapsed endosperm and cracked pericarp (Styer and Cantliffe, 1984).
5. High sugar content elevates osmotic potential which may cause cell membrane and pericarp damage (imbibition damage), and a consequent increased leaching of sugars from the seeds. This reduces metabolic energy available for embryo growth during germination, and also stimulates the growth of pathogenic micro-organisms (Headrick *et al.*, 1990).

Poor germination, establishment problems and below optimal and/or uneven plant populations are features of super-sweet corn (Juvic *et al.*, 1993). The presence of seed-and soil-borne pathogens, particularly *Fusarium* spp., is one of the factors that can affect the emergence

and establishment performance of super-sweet corn. In this paper we report the effects of *Fusarium* spp. on two seed lots of a super-sweet corn cultivar.

Materials and Methods

Two commercial captan-treated seed lots of super-sweet corn cv. Illini Gold from the 1991 harvest were purchased in August 1991. For each seed lot, percentage germination and thousand seed weight were determined using internationally standardised methodology (ISTA, 1993). Mechanical damage was assessed by visual examination of three replicates of 100 seeds, with seeds with pericarp cracks, collapsed pericarp, and/or parts of the pericarp or endosperm missing being classified as damaged. The presence of seed-borne *Fusarium* spp. was detected by plating four replicates of 100 surface sterilised (1% NaOCl for 2 min) seeds onto potato dextrose agar (PDA) and incubating at 25°C for 5 days. Fungi were identified using colony and conidial characteristics (Kabeere pers. comm.).

Three spring sowings (29 October, 28 November, 23 December 1991) were made at Massey University into an Ohakea silt loam soil previously cropped with barley and maize. After glyphosate desiccation (7 October) the field was ploughed (14 October) and harrowed twice (17 October, 26 October). At each sowing, seeds were hand-planted at a depth of 2-2.5 cm creating six row plots (4.5 x 6m) with an inter-row spacing of 75 cm and an intra-row spacing of 15 cm, equivalent to a sowing rate of 13.3 kg/ha (40 seeds/row). There were four randomly arranged replicates (plots) for each seed lot x sowing date. A compound fertiliser (12N:10P:10K:1S:6Ca) was broadcast at a rate of 230 kg/ha before the final harrowing (October) or rotary cultivation (November and December), and a mixture of alachlor (2.88 kg a.i./ha) plus atrazine (1.5 kg a.i./ha) applied 3 days after each sowing. Methiocarb (2.34 kg a.i./ha) was applied as Mesurol baits 7 days after each sowing, while urea (290 kg/ha) was applied as a side dressing 50 days after each sowing. Further details of crop and seed development are provided by Mashauri (1993).

Seedling emergence was counted daily from each row of each plot until no further increase was recorded. At the 5th leaf stage (Mashauri, 1993) for each sowing, the number of plants within the middle two rows of each plot were recorded, and establishment determined by expressing these data as a percentage of the number of seeds sown. From the other two rows per plot, diseased seedlings were randomly selected, removed from the soil, and lesioned tissue surface sterilised and plated onto PDA. Suspected *Fusarium* pathogens were sub-cultured onto PDA and identified as previously described.

Cobs were hand harvested on 20 June, 28 June and 10 July 1992 for the October, November and December sowings respectively, dried using a heater-air mini drier system (Mashauri, 1993), then hand-shelled. The incidence of seed-borne pathogens was then determined using four replicates of 100 surface sterilised seeds per harvest.

Seeds of the original two seed lots were stored in sealed aluminium foil bags at 5°C for 14 months before the incidence of seed-borne *Fusarium* spp. was re-determined. Both seed lots were then hand-sown (3 x 100 seeds/seed lot) on 17 November 1992 into field plots 50 x 70 cm (5 rows x 20 cm apart) with 20 seeds/row and 3 cm between seeds. The site was adjacent to that used for the 1991 trial, but had not grown maize in the previous 2 years. Plots were covered with a wire mesh cage to prevent bird damage, and seedling emergence was determined 14 days after planting by counting the number of seedlings in each row.

Results

Small but statistically significant differences between the two seed lots for thousand seed weight and mechanical damage were recorded (Table 1), with the larger seed having a greater percentage of damaged seeds. However, the two seed lots did not differ in germination. Both seed lots had 12% abnormal seedlings, which included deformed seedlings and decayed seedlings with severe rotting of the shoot base. Both seed lots contained high levels of *F. subglutinans* (Wollenw. and Reinking) (Nelson *et al.*, 1983). (Table 1), the only other fungus present being a *Penicillium* spp. which was detected in 6-8% of the seeds.

Field emergence did not differ between the two seed lots at any of the three sowing dates (Table 2), but did increase as sowing date was delayed. Emergence from the December sowing was greater ($P>0.05$) than for the October sowing. Similarly, establishment did not differ between the two seed lots (Table 2), but conversely decreased ($P>0.05$) as sowing date was delayed. For the October and November sowings, the majority of plants which emerged survived (average loss = 8%), but for the December sowing nearly half of the seedlings which originally emerged failed to survive. These losses occurred as a result of post-emergence damping-off and seedling blight, with damage being mainly localised on the seedling mescotyls near ground level, and occasionally on the root systems. Species isolated from this tissue were predominantly *F. subglutinans* and *F. graminearum* Schwabe.

Table 1. Quality parameters for two seed lots of super-sweet corn cv. Illini Gold.

Seed Lot	Thousand seed weight (g)	% seeds mechanically damaged	% germination	% seeds carrying *Fusarium subglutinans*
1	162	66	88	60
2	138	52	86	82
LSD (p<0.05)	5.1	6.7	NS	NS

Table 2. Field performance for two seed lots of super-sweet corn cv. Illini Gold at three sowing dates

	% field emergence[1]				% establishment[1,2]			
Seed lot	29 Oct	28 Nov	23 Dec	LSD (P<0.05)	29 Oct	28 Nov	23 Dec	LSD (P<0.05)
1	64	70	80	9.7	55	62	32	14.3
2	62	70	75	11.2	60	68	38	10.7
LSD (P<0.05)	NS	NS	NS		NS	NS	NS	

[1] plants/m^2 as percentage of seeds sown

[2] assessed at the 5th leaf stage

Harvested cobs had symptoms of *Fusarium* infection which ranged from growth of fungal mycelium on the bottom of the shanks only, to damage to the tops and/or bottoms of cobs, to cobs completely covered by fungal mycelium. Seed-borne inoculum was greatest in seeds from the October sowing, and decreased as sowing was delayed (Table 3). *Fusarium* species identified included *F. subglutinans, F. graminearum* and *F. poae* (Peck) Wollenw., but other non-identified *Fusarium* species were also present (Table 3).

Re-testing of the two original seed lots following 14 months of storage at 5°C showed that the incidence of *F. subglutinans* had fallen to 4% (seed lot 1) and 13% (seed lot 2). Field emergence was 90% for seed lot 1 and 82% for seedlot 2.

Discussion

Although over 50% of the seeds in both seed lots exhibited mechanical damage, the germination of both was reasonably high (>80%). Escasinas (1986) demonstrated that the extent of mechanical (or cracking) damage *per se* bears little relation to loss of germinability; rather it is the position of the damage in relation to the embryo which is important. This result indicates that mechanical damage was therefore unlikely to have been a primary factor in the field emergence recorded, particularly as the December sowing field emergences were only 6-10% lower than the germination test results. As indicated by the levels of seed-borne *F. subglutinans*, and the reasons for the abnormal seedlings recorded in the germination test, seed-borne *F.*

Table 3. *Fusarium* spp. recorded from harvested seeds of super-sweet corn cv. Illini Gold.

	Percentage of seeds infected with *Fusarium* spp.				
Sowing date	*F. subglutinans*	*F. graminearum*	*F. poae*	Other *F.* spp	Total
29 October	24	27	17	22	90
28 November	18	32	15	14	79
23 December	14	32	12	9	67

subglutinans, and soil-borne *F. graminearum* were likely to be the major causes of the poor field performance of the two seed lots.

Fusarium subglutinans (syn. *F. sacchari* (Butler) Gams var. *subglutinans* (Wollenw. and Reinking) Nirenberg; *F. moniliforme* Sheldon var. *subglutinans* Snyd., Hans and Oswald; Nelson *et al.*, 1983) is one of the most virulent *Fusarium* species, and has been previously reported to substantially reduce germination and seedling emergence through seed rotting and pre- and post-emergence damping off (Gilbertson *et al.*, 1985). While the optimum temperature for growth of this pathogen is 20-25°C (Gonzales *et al.*, 1988), seedling death from attack by the fungus can be prevalent at soil temperatures of 10-13°C (Shurtleff, 1980). *Fusarium graminearum* is both seed and soil transmitted, the seed-borne phase usually producing seedling blights while the soil-borne phase usually causes root and foot rots (Cook, 1968). Maize seedling diseases caused by this pathogen are more frequent during periods of cool weather when plants grow slowly (Christensen and Wilcoxson, 1966), although as with all pathogens, factors such as host genotype and resistance, and inoculum levels, type and location in the soil relative to the seed, are also important (Agarwal and Sinclair, 1987).

Field emergence increased as sowing was delayed, demonstrating the importance of temperature for maize seedling emergence (Eagles and Hardacre, 1979). Soil 10 cm temperatures for the week after sowing ranged from 11-14°C (October), 12-15°C (November) and 17-19°C (December), and emergence rate (days to maximum emergence) was 15, 11 and 7 for the October, November and December sowings respectively (Mashauri, 1993). The longer seedlings take to emerge, the more prone they are to damage by seed and soil-borne fungi (Kruger, 1989). However, post-emergence losses were greatest from the December sowing, which was characterised by <1mm of rain and maximum air temperatures of 18-21°C during the 14 day period following maximum emergence (Mashauri, 1993). Stem and stalk rots caused by *F. subglutinans* and *F. graminearum* are more severe under warm, dry than cold, wet conditions (Christensen and Wilcoxson, 1966).

From seed-and/or soil-borne initial inoculum sources, cobs were heavily infected by *Fusarium* spp; however, the higher incidence in seeds harvested from the October sowing was probably a reflection of harvest date (145, 134 and 119 days after sowing for the October, November and December sowings respectively; Mashauri, 1993), in that the longer cobs remain in the field before harvest, the greater opportunity there is for fungal invasion and contamination (Shurtleff, 1980).

Storage of seed at low seed moisture content (<10%) and temperature (5°C or below) prolongs seed storage life, but does not necessarily prevent continued fungal degradation in seed since members of the *Fusarium* group are still active at 5°C (Christensen and Kaufmann, 1974). However, *F. subglutinans* does not appear to have this ability, as the pathogen was almost eliminated following storage at 5°C for 14 months. In comparison with the November, 1991 sowing, field emergence of this stored seed in 1992 was 12-20% greater, demonstrating the significant effects of both seed and soil-borne *Fusarium* inoculum.

Only two fungicide seed treatments, captan (Orthocide 80W) and carboxin plus thiram (Vitaflo 200) are currently registered for maize and sweetcorn (Walton and Walton, 1993), and only the latter provides some control of *Fusarium* spp. For other cereals, the seed treatment flutriafol plus imazalil sulphate (Vincit) controls *Fusarium* spp. in wheat, barley and oats, while fuberidazole (Bayer Fuberidazole) is registered as a seed treatment specifically for the control of *Fusarium* spp. in cereals (Walton and Walton, 1993). The incidence of *Fusarium* spp. in super-sweet corn seed lots in New Zealand is not known, but the two seed lots used in this study were selected at random from those available commercially. If they are typical of seed lots being offered for sale, then seed treatment with a systemic product specifically for *Fusarium* control would help to improve their field performance, both by controlling seed-borne inoculum, and also affording some protection from soil-borne inoculum.

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References

Agarwal, V.K. and Sinclair, J.B. 1987. Principles of Seed Pathology, CRC Press, Florida, USA.

Bewley, J.D. and Black, M. 1978. Physiology and Biochemistry of Seeds, Springer-Verlag, New York, USA.

Christensen, C.M. and Kaufmann, H.H. 1974. *In:* Storage of Cereal Grains and their Products (ed. C.M. Christensen), pp. 158-182. American Association of Cereal Chemists, Minnesota, USA.

Christensen, C.M. and Wilcoxson, R.D. 1966. Stalk rot of corn. Monograph No. 3, American Phytopathology Society, St Paul, Minnesota, USA.

Churchill, G.A. and Andrew, R.H. 1983. Effects of two maize endosperm mutants on kernal maturity, carbohydrates and germination. *Crop Science* ***24***, 76-81.

Cook, R.J. 1968. *Fusarium* root and foot rot of cereals in the Pacific Northwest. *Phytopathology* ***58***, 127-131.

Eagles, H.A. and Hardacre, A.K. 1979. Genetic variation in maize for early germination and emergence at 10°C. *Euphytica* ***28***, 287-295.

Escasinas, A.B. 1986. A study of the cause of seed deterioration following processing in maize. Unpublished MAgrSc Thesis, Seed Technology Centre, Massey University, Palmerston North.

Ferguson, J.E., Dickinson, D.B. and Rhodes, A.M. 1978. Genetics of sugary enhancer (su), an independent modifier of sweet corn. *Journal of Heredity* ***69***, 377-380.

Gilbertson, R.L., Brown, W.M. Jr. and Ruppel, E.G. 1985. Prevalence and virulence of *Fusarium* spp. associated with stalk rot of corn in Colorado. *Plant Disease* ***69***, 1065-1068.

Gonzales, J.W., Rhodes, A.M. and Dickinson, D.B. 1976. Carbohydrate and enzyme characterisation of a high sucrose sugary inbred line of sweet corn. *Plant Physiology* ***58***, 28-32.

Gonzales, H.H.L., Resnik, S.L. and Vaamonde, G. 1988. Influence of temperature on growth rate and lag phase of fungi isolated from Argentine corn. *International Journal of Food and Microbiology* ***6***, 179-183.

Headrick, J.M., Pataky, J.K. and Juvik, J.A. 1990. Relationships among carbohydrate contents of kernels, condition of silk after pollination, and the response of sweet corn inbred lines to infection of kernels by *Fusarium moniliforme*. *Phytopathology* ***80***, 487-494.

Herter, U. and Burris, J.S. 1989. Effect of drying rate and temperature on drying injury of corn seed. *Canadian Journal of Plant Science* ***69***, 763-774.

ISTA 1993. International rules for seed testing. Supplement to *Seed Science and Technology* ***21***, 1-288.

Juvic, J.A., Jangulo, M.C., Headrick, J.M. and Pataky, J.K. 1993. Kernal changes in a shrunken maize population associated with selection for increased field emergence. *Journal of the American Society of Horticultural Science* ***118***, 135-140.

Kruger, W. 1989. Maize diseases caused by *Fusarium*: involved species and mycotoxins. *In: Fusarium*: Mycotoxins, Taxonomy and Pathogenicity (ed. J. Chelkowski), Elsevier, The Netherlands.

Mashauri, I.M. 1993. Effects of seed vigour on seed production and quality in *Zea mays* L. cv. Illini Gold. Unpublished MAgrSc Thesis, Seed Technology Centre, Department of Plant Science, Massey University, Palmerston North.

Nelson, P.E., Toussoum, T.A. and Marasas, W.F.O. 1983. *Fusarium* species: an illustrated manual for identification. PSU Press, Pennsylvania, USA.

Shurtleff, M.C. (ed). 1980. Compendium of Corn Diseases, 2nd Edition, American Phytopathology Society. St Paul, Minnesota, USA.

Styer, R.C. and Cantliffe, D.J. 1983. Relationship between environment during seed development and seed vigour of two endosperm mutants of corn. *Journal of the American Society of Horticultural Science* ***108***, 717-720.

Walton, A. and Walton, T. 1993. New Zealand Agricultural and Plant Protection Manual, No 4, January 1993. WHAM Chemsafe Ltd, Wellington.

Wilson, D.O. and Trawatha, S.E. 1991. Physiological maturity and vigour in production of "Florida staysweet" shrunken - 2 sweet corn seed. *Crop Science* ***31***, 1640-1647.