Seedling Emergence Responses to Corn Seeds Coated with Starch Containing Entrapped EPTC

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EPTC (*S*-ethyl dipropylcarbamothioate) incorporated within a starch matrix and coated on corn seed planted along with oats or giant foxtail reduced seedling number and heights of oats during 10 days of growth and giant foxtail during 17–35 days of growth. Levels of EPTC of about 0.1 mg/seed controlled over 95% of the oat growth, and levels of about 0.3 mg/seed controlled 50% of the foxtail. Fine-textured soils induced greater growth in corn seedlings, but coarse-textured soils favored better control of oats and foxtail. Influences of coating variables, seed variety, starch type, soil type, and use of the EPTC safener R-25788 (*N,N*-diallyldichloroacetamide) are discussed.

The advantages of coating or encapsulating seeds have been reviewed (Nikolskaya and Svirskaya, 1984). Benefits include increasing the size and improving the shape of seeds for more accurate mechanical sowing, protecting seeds from unfavorable winter conditions to allow preseason planting, and providing a means of incorporating various adjuvants such as fertilizers, pesticides, growth promoters, etc., into the vicinity of the seed useful for its subsequent growth and survival.

Care must be taken not to sacrifice the germinative capacity of the seeds in various coating treatments. One patent (Kirk, 1972) stresses the need for a porous coating, such as finely divided expanded vermiculite, which will allow for the exchange of water, oxygen, carbon dioxide, and other metabolic products between the germinating seed and its environment. Porous coatings may be provided by either inorganic or organic materials, and polymers such as poly(vinyl alcohol) and poly(vinyl acetate) may be used as binders.

Our objective was to prepare seed coatings based upon starch that would be capable of providing many advantages through their hydrophilicity and matrix-forming capacities. Starch has a unique capacity of forming a matrix that can entrap pesticides and other materials (Shasha et al., 1976, 1981; Trimnell et al., 1982).

The focus of this work involves the use of the herbicide EPTC (*S*-ethyl dipropylcarbamothioate) in starch-coated corn seeds as a model for the control of weed and seedling development in field crops. Earlier studies (Schreiber et al., 1978; Schreiber and White, 1980a,b) showed that EPTC, provided as cells entrapped within a starch matrix and applied to soil, provided sustained release of herbicide over an extended period with reduced loss due to volatility and leaching. Phytotoxicity to desirable plants was diminshed, and the herbicide was more effectively maintained at the point of application. Reports of the successful use of EPTC in alfalfa seed coatings (Dawson, 1983a,b) encouraged us to attempt the use of EPTC entrapped or encapsulated in starch for the coating of corn seeds as a vehicle that would minimize damage to the growth of corn seedlings while maximizing control of the growth of undesirable plant species in the vicinity of the corn. Preparations of these seed coatings and determination of their effects upon the growth of corn, oat, and giant foxtail seedlings in greenhouse trials are described.

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MATERIALS AND METHODS

Corn (*Zea mays* L.) seeds were Pioneer hybrid 3747 and fungicide-treated DeKalb hybrids XL72aa (EPTC tolerant) and XL55a (EPTC sensitive). Oat (*Avena sativa* L.) seeds were Ogle variety, locally supplied. Starches were pearl corn and waxy maize containing 10% moisture. EPTC was supplied as emulsifiable concentrates (ECs) Eptam 7.0 E (no safener) and Eradicane 6.7 E (EPTC+) containing safener R-25788 (*N,N*,-diallyldichloroacetamide). Pelletized urea and sodium hydroxide were reagent grade. Sets of greenhouse experiments involving oats were conducted using as soil Redi-Earth Peat Lite mix, a mixture of peat, vermiculite, and plant nutrients. The initial pH of the soil was 5.8. Experiments involving giant foxtail (*Setaria faberi* Herrm.) were conducted in silt loam and silt loam–sand (2:1) soils.

Preparation of Starch- and Herbicide-Coated Seeds. Corn seeds were coated with starch pastes formed by gelatinizing the starch with either sodium hydroxide or urea solutions. EPTC was introduced either by dispersing the liquid herbicide into the paste prior to coating or by adding powdered starch borate encapsulated EPTC passing 35 mesh (Trimnell et al., 1982) to paste-coated seeds. The seeds were air-dried and separated manually.

Sodium hydroxide gelatinized starch paste was prepared by mixing in a Waring Blendor starch (45 g) and water (70 mL) followed by sodium hydroxide solution (6.6%, 50 mL) and additional water (60 mL). The final pH was near 13. Urea-gelatinized starch paste was obtained similarly by mixing starch (10 g) into a solution of urea (50 g) in water (50 mL). The final pH was near neutral. Paste viscosities were determined on a Brookfield LVF viscometer at 6 rpm. EPTC was dispersed into the pastes at ratios of 5–20 g of paste/50 g of seeds. Pastes not containing dispersed EPTC (4 g) were used to stick starch borate encapsulated EPTC (9–13% active ingredient) onto the surface of seeds (2 g of encapsulated EPTC/50 g of seeds). The seeds were coated with an additional 4 g of paste and air-dried. Controls comprised both uncoated and starch-coated seeds free of herbicide.

EPTC contents were determined by GLC (gas–liquid chromatography) after release from starch–EPTC granules or starch–EPTC seed coatings by treatment with either aqueous acid or buffered enzyme solutions to degrade the starch. Granules containing EPTC (100 mg) or corn seeds containing EPTC (10 g) were either digested 5 min on a steam bath with HCl (2 N, 10 mL) under an extracting layer of isooctane (25 mL) or suspended 1 h at 25 °C in a solution of 1% Amizyme TX-8[13] at pH 6.0 in 0.1 M phosphate buffer (1 mL/seed) under isooctane (1 mL). GLC was conducted on the isooctane extracts isothermally at a column temperature of 120 °C using butylate [*S*-ethyl bis(2-methylpropyl)carbamothioate] as internal standard,

Table I. Stability of Starch Pastes in Seed Coating Formulations

formulation[a]	viscosity,[b,c] cP × 10^{-3} init	2 h	18 h
alkali waxy maize (0.45 N)[d]	16.0	33.0	28.0
alkali waxy maize (0.45 N) containing EPTC[d]	10.0	16.0	18.0
alkali pearl starch (0.45 N)[d]	47.0	100+	100+
alkali pearl starch (0.45 N) containing EPTC	50.0	100+	100+
alkali pearl starch (0.67 N) containing EPTC[d]	16.0	23.0	18.0
alkali pearl starch (0.90 N) containing EPTC[d]	14.0	20.0	10.0
urea waxy maize[e]	3.0	4.6	2.4
urea waxy maize containing EPTC[e]	7.1	7.2	6.6
urea pearl starch	4.0	15.5	37.0
urea pearl starch containing EPTC[e]	5.7	30.0	100+

[a] Number in parentheses is normality of sodium hydroxide in the alkali starch paste. [b] Viscosity measured with a Brookfield LVF viscometer at 6 rpm. [c] Readings are in thousands of centipoise. [d] 10 g of EPTC/225 g of alkali starch paste (starch, 45 g; alkali, 180 g). [e] 8 g of EPTC/110 g of urea starch paste (starch, 10 g; urea, 50 g; water, 50 g).

Table II. Retentions of EPTC or EPTC+[a] in Corn Seed Coatings Using Pearl and Waxy Maize Starches

corn treatment[b]	EPTC recovery,[c] %, pearl	EPTC recovery,[c] %, waxy	flaking,[d] mg, pearl	flaking,[d] mg, waxy	EPTC/seed, mg, pearl	EPTC/seed, mg, waxy
alkali starch dispersed EPTC						
e	78	69	10.1	22.2	0.13	0.12
f	79	82	22.8	19.5	0.62	0.68
g	70	62	86.9	110.0	0.25	0.21
h	62	57	270.2	883.6	0.51	0.34
alkali starch dispersed EPTC+[i]	71	51	520.5	993.4	0.44	0.32
alkali starch encapsulated EPTC[j]	68	61	152.4	731.2	0.52	0.48
alkali starch encapsulated EPTC+[j]	69	53	178.6	464.6	0.54	0.44
urea starch dispersed EPTC[k]	75	64	14.8	33.4	0.56	0.39
urea starch dispersed EPTC[l]	74	61	16.1	13.1	1.06	0.74
urea starch dispersed EPTC+[k]	72	64	15.1	39.4	0.47	0.46
urea starch encapsulated EPTC[m]	100	94	49.7	23.2	0.79	0.71
urea starch	80	84	37.2	15.4	0.68	0.64

[a] EPTC+ is EPTC with protectant R-25788. [b] Corn variety is untreated Pioneer 3747 (50 g/treatment). [c] Percent of active ingredient retained on the dried corn seeds that was present on the freshly coated seeds. [d] Milligrams of flaked from 50 g of corn seeds. [e] Seeds coated with starch paste (5 g) prepared by blending EPTC (2.5 g) in alkali starch paste (225 g). [f] Seeds coated with starch paste (5 g) prepared by blending EPTC (10 g) in alkali starch paste (225 g). [g] Seeds coated with 10 g of paste *e*. [h] Seeds coated with 20 g of paste *e*. [i] Seeds coated with 20 g of paste *e* made with EPTC+. [j] Seeds coated with alkali starch paste (4 g), encapsulated EPTC or EPTC+ (2 g), and coated again with alkali starch paste (4 g). [k] Seeds coated with starch paste (6 g) prepared by blending EPTC or EPTC+ (4 g) in urea starch paste (110 g). [l] Seeds coated with starch paste (6 g) prepared by blending EPTC (8 g) in urea starch paste (110 g). [m] Seeds coated with urea starch paste (4 g), encapsulated EPTC or EPTC+ (2 g), and coated again with urea starch paste (4 g).

Table III. Effects of Various Corn Seed Treatments on the Growth of Corn and Oats in a Peat-Vermiculite Mix

corn treatment	mg of EPTC/seed	plant ht 10 days after planting, cm: corn[a], without oats	corn[a], with oats	oats[b], without corn	oats[b], with corn
uncoated control	none	26.4 a[c]	21.9 ab[c]	101.5 a[c]	94.9 a[c]
alkali starch[d] control	none	22.1 ab	19.3 abc		81.1 ab
alkali starch dispersed EPTC	0.51	22.6 ab	20.7 abc		0 c
alkali starch dispersed EPTC+	0.52	20.1 abc	19.6 abc		0 c
alkali starch encapsulated EPTC[e]	0.69	18.9 abc	16.4 bc		0 c
alkali starch encapsulated EPTC+[f]	0.67	19.6 abc	18.9 abc		0.1 c
urea starch control	none	17.6 bc	14.1 c		69.2 b
urea starch dispersed EPTC	0.54	13.3 c	14.5 c		0 c
urea starch dispersed EPTC+	0.51	15.2 bc	14.8 c		0 c
urea starch encapsulated EPTC[e]	0.86	15.4 bc	14.3 c		0 c
urea starch encapsulated EPTC+[f]	0.73	16.3 bc	15.2 bc		0 c

[a] Mean values of 20 replications. [b] Mean values of the sums of 10 oat seeds grown in 20 replications. [c] Means involving corn growth followed by the same letter within a row or column and means involving oats growth followed by the same letter in a column are not significantly different at the 5% level according to Duncan's multiple-range test. [d] Pearl starch used in all coatings. [e] 9.6% active ingredient in encapsulated material. [f] 13.0% active ingredient in encapsulated material.

since EPTC and butylate are readily separated under these conditions. The GLC was performed on a Tracor 560 with hydrogen flame ionization detection. The column consisted of 1.8 m × 3.2 mm (o.d.) nickel tubing packed with Chromosorb WHP, 150–175 μm, coated with 3% OV-1 silicone rubber.

Seedling Growth Experiments. Oat growth experiments in the presence of coated corn seeds were designed to determine the influence of coating variables and EPTC levels upon the growth of both oat (susceptible) and corn (resistant) seedlings. Growth experiments using giant foxtail (*Setaria faberi* Herrm.) (susceptible) were designed to determine influences of soil type and corn variety upon the growth of foxtail and corn seedlings (Tables I–III).

Coating variables in the oat growth experiments included pearl starch gelatinized with sodium hydroxide or urea solutions containing EPTC or EPTC+, either dispersed in the gelatinized starch or added as a solid form

Table IV. Effects of Corn Coated with Starch Containing Various Levels of Dispersed EPTC on the Growth of Corn and Oats in a Peat-Vermiculite Mix

	plant ht 10 days after planting, cm			
	corn[b]		oats[c]	
corn treatment,[a] mg of EPTC/seed	without oats	with oats	without corn	with corn
uncoated control	14.3 abc[d]	13.4 bc[d]	179.2 a[d]	122.3 b[d]
coated control	15.3 abc	13.0 c		110.6 b
0.12	18.8 a	17.2 abc		6.4 c
0.23	18.6 ab	12.9 c		2.9 c
0.45	16.4 abc	14.2 abc		1.4 c

[a] Corn controls and corn coated with alkali pearl starch containing the average indicated amounts of dispersed EPTC. [b] Mean values of 10 replications. [c] Mean values of the sums of 20 oat seed grown in 10 replications. [d] Means involving corn growth followed by the same letter within a row or column and means involving oats growth followed by the same letter in a column are not significantly different at the 5% level according to Duncan's multiple-range test.

encapsulated in starch borate. Controls included uncoated corn seeds and seeds coated with sodium hydroxide or urea-dispersed starches not containing EPTC. Twenty replicates of one corn seed of each treatment or control (Pioneer 3747) were placed into 170-g paper cups with 10 oat seeds and 15 g of Redi-Earth Peat Lite mix. Similar series of 20 replicates of these seeds were set up, but without oat seeds. Twenty replicates of 10 oat seeds were grown without corn seeds. The replicates were treated with 20 mL of water and covered for 5 days. The water lost by evaporation was restored daily. The covers were removed after 5 days, and the heights of corn and the cumulative heights of oat seedlings were recorded at 10 days.

EPTC levels (Table IV) of 0.12, 0.23, and 0.45 mg of EPTC/seed were obtained by coating 50 g of corn seeds (Pioneer 3747) with 5, 10, and 20 g of sodium hydroxide dispersed pearl starch containing dispersed EPTC (2.5 g of EPTC/225 g of paste), followed by air-drying and manual separation of seeds. Ten replicates of one corn seed of each EPTC level were placed into 450-g paper cups with 20 oat seeds and 28 g of Redi-Earth Peat Lite mix. Similar series of 10 replicates of these seeds were set up without oat seeds. Ten replicates of 20 oat seeds were grown without corn seeds. Series of replicates of untreated corn seeds, with and without 20 oat seeds, and 10 replicates of coated corn seeds prepared from 20 g of starch paste/50 g of seeds, with and without oats, were used as controls.

Giant foxtail growth experiments were conducted utilizing corn seeds coated with waxy maize gelatinized with sodium hydroxide and containing dispersed EPTC+ at levels of 0.19–0.36 mg of active ingredient/seed.

Influences of soil type were determined by comparing growth in silt loam and silt loam–sand (2:1) soils. Sixteen replicates (Table V) of one coated corn seed (Pioneer 3747) were planted in 10-cm-diameter plastic pots filled with silt loam soil and 50 giant foxtail seeds, having a germination rate of about 50%. Eight replicates (Table VI) of one coated corn seed were planted in similar pots filled with silt loam and 75 giant foxtail seeds. Eight replicates (Table VI) of one coated corn seed were planted in 2:1 silt loam–sand and 75 giant foxtail seeds. Uncoated corn seeds were used as controls. Thirty-five days after planting, corn seedling heights, fresh weights, and giant foxtail numbers, heights, and fresh weights were determined.

The influence of corn seed coating, with and without herbicide, upon the growth of corn and giant foxtail was determined. Ten replicates (Table VII) of one corn seed (Pioneer 3747) were planted in silmilar pots filled with 2:1 silt loam–sand soils and 75 giant foxtail seeds. Ten replicates (Table VII) contained EPTC+, 10 were without EPTC+, and 10 were uncoated. Seedlings were evaluated as above 17 days after planting.

Table V. Effects of Corn Coated with Encapsulated EPTC+[a] on Growth of Corn and Giant Foxtail in a Silt Loam Soil[b]

	plant measmt 35 days after planting				
	corn		giant foxtail		
corn treatment	ht, cm	fresh wt, g	no.	ht, cm	wt/plant, g
untreated seed	57.5 b[d]	6.79 a	21.2 a	17.7 a	0.119 a
seed coated with EPTC+ (0.32 mg)[c]	62.0 a	7.27 a	18.3 a	11.4 b	0.093 a

[a] EPTC+ is EPTC with protectant R-25788. [b] Mean values of 16 replications. [c] Number in parentheses is milligrams of EPTC+ coated on each corn seed (Pioneer 3747). [d] Means within a column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple-range test.

Table VI. Interaction of Corn Coated with Encapsulated EPTC+[a] and Soil Texture on Growth of Corn and Giant Foxtail[b]

	plant measmt 35 days after planting				
	corn		giant foxtail		
corn treatment[c]	ht, cm	fresh wt, g	no.	ht, cm	wt/plant, g
untreated seed					
silt loam + sand (2:1)	58.1 b[d]	5.26 b	44.8 a	15.4 a	0.076 a
silt loam	59.9 b	6.87 b	23.6 bc	17.1 a	0.122 a
EPTC+-coated seed					
silt loam + sand (2:1)	56.7 b	5.44 b	30.4 b	7.8 b	0.066 a
silt loam	72.7 a	10.76 a	18.2 c	8.4 b	0.077 a

[a] EPTC+ is EPTC with protectant R-25788. [b] Mean values of eight replications. [c] Corn variety (Pioneer 3747) coated with 0.32 mg of EPTC+ on each corn seed. [d] Means within a column followed by the same letter are not significantly different at 5% level according to Duncan's multiple-range test.

Table VII. Effects of Corn Seed Coating on the Growth of Corn and Giant Foxtail in a Silt Loam–Sand Mix (2:1)[a]

	plant measmt 17 days after planting				
	corn		giant foxtail		
corn treatment[b]	ht, cm	fresh wt, g	no.	ht, cm	wt/plant, g
seed coated with EPTC+ (32 mg)	47.9 a[c]	3.20 a	19.6 b	7.3 b	0.046 a
seed coated, no herbicide	53.0 a	3.48 a	40.9 a	11.5 a	0.046 a
seed not coated, no herbicide	48.7 a	3.17 a	36.3 a	11.1 a	0.042 a

[a] Mean values of 10 replications. [b] Number in parentheses is milligrams of EPTC+ coated on each corn seed (Pioneer 3747). [c] Means within a column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple-range test.

Influences of corn variety upon the growth of corn and giant foxtail in the presence of entrapped EPTC+ were determined by comparing results of coating DeKalb XL72aa (EPTC tolerant), DeKalb XL55a (EPTC sensitive), and Pioneer 3747 corn seeds in growth experiments. Eight replicates (Table VIII) of one coated corn seed were planted in similar pots filled with 2:1 silt loam–sand soils and 75 giant foxtail seeds, using each of the indicated corn seed types. Eight replicates of untreated seeds of each type were planted similarly. Seedlings were evaluated 28 days after planting.

RESULTS AND DISCUSSION

For a starch dispersion containing a herbicide to be useful as a seed coating, the following requirements should

Table VIII. Interactions of Corn Variety and Corn Seed Coating on Growth of Corn and Giant Foxtail in a Silt Loam-Sand Mix (2:1)[a]

	plant measmt 28 days after planting				
	corn		giant foxtail		
corn treatment[b]	ht, cm	fresh wt, g	no.	ht, cm	wt/plant, g
Dekalb XL72aa					
seed coated, EPTC (0.36 mg)	51.0 a[c]	6.16 a	15.8 abCD	7.8 bBC	0.081 abAB
seed coated, EPTC+ (0.34 mg)	59.4 a	5.57 a	13.9 b D	6.4 bC	0.063 b B
seed not coated, no herbicide	61.3 a	6.15 a	21.2 a BC	14.2 aA	0.097 a A
Dekalb XL55a					
seed coated, EPTC (0.35 mg)	30.6 a	2.99 b	15.4 b CD	9.0 bB	0.097 a A
seed coated, EPTC+ (0.19 mg)	43.9 a	4.17 ab	25.6 a AB	14.0 aA	0.089 a AB
seed not coated, no herbicide	62.5 a	6.15 a	28.8 a A	16.1 aA	0.092 a AB
Pioneer 3747					
seed coated, EPTC+ (0.32 mg)	53.2 a	4.33 a	13.6 b D	7.6 bBC	0.070 a AB
seed not coated, no herbicide	61.0 a	5.41 a	27.0 a AB	15.7 aA	0.095 a A

[a] Mean values of eight replications. [b] Number in parentheses is milligrams of EPTC+ coated on each corn seed. [c] Means within a variety in a column followed by the same lower-case letter are not significantly different at the 5% level according to Duncan's multiple-range test. Means among varieties in a column followed by the same capital letter are not significantly different at the 5% level according to Duncan's multiple-range test.

be met: the dispersion needs to be stable as a paste; it needs to be used at a low ratio of paste to seed (5 g or less/50 g of seed); it should be capable of adhering to and forming a thin film on the seed; it should not be deleterious to seed germination.

Stable pastes are essential for uniform and reproducible seed coatings. Alkali pearl starch pastes as initially prepared were about 0.45 N in alkalinity and were unstable, changing in viscosity from about 47000 to over 100000 cP in 2 h (Table I). The instability was overcome by increasing the alkalinity to 0.67–0.90 N, where 18-h viscosities were similar to initial viscosities. Stable viscosities at 0.45 N could be achieved by changing to waxy maize. The absence of a linear amylose fraction in this starch prevented the viscosity increases due to retrogradation of amylose through alignment of starch chains. With pearl starch, when alkalinity was increased, the increasing negative charge on the starch chains induced by increased alkali content caused repulsion and prevented alignment. Urea–waxy maize pastes, in both the absence and presence of EPTC, showed good stability (Table I). Pastes based upon urea–pearl starch were unstable, and the presence of EPTC increased the instability, suggesting possible adduct formation between EPTC and the starch.

Comparisons of various starch systems as to their effectiveness for seed coating are shown in Table II. When alkali starch was used, flaking of coating from the seed was minimal with lower amounts of paste but excessive with higher amounts. Flaking was low with urea–starch pastes in all systems. Pastes made with waxy maize had greater tendencies to flake than those made with pearl starch but still produced coatings having a useful EPTC range. The tendency toward retrogradation in the pearl starch may produce a tougher coat less prone to flaking. Losses of EPTC through volatilization in the preparation of the coatings were minimized by using encapsulated EPTC in the coating rather than an EPTC dispersion.

The effects of various starch–herbicide corn seed coatings upon growth of oats are seen in Table III. Growth of oats was almost totally suppressed in every treatment containing herbicide, suggesting that herbicide levels at or beyond 0.5 mg/seed greatly exceeded threshhold levels. The use of urea in seed coatings caused some damage to the corn, and the average corn seedling growth was significantly less than in treatments where urea was absent. No significant differences were observed in corn growth among uncoated checks and alkali starch coated seeds, with or without various EPTC and EPTC+ treatments. Herbicide treatments did not cause additional damage to urea–starch-coated seeds. Corn germination was 98% complete in 10 days.

The results of growing experiments were designed to determine the threshhold level for oat controls are shown in Table IV, where corn seeds coated with lower levels of herbicide (0.12–0.45 mg/seed), larger cups, greater amounts of soil, and larger numbers of oat seeds were used. Table IV shows that even at the level of 0.12 mg of EPTC/seed there was over 95% suppression of oats growth. In these experiments, untreated corn and the control coated corn had some significant effect upon growth of the oats.

Herbicide levels in seed coatings varied considerably from seed to seed depending upon variations in size and shape of seeds and thickness of coating. Herbicide analyses for individual seeds showed variations as much as 100% among seeds. For example, analyses of 10 individual seeds from one experiment averaged 0.26 mg of EPTC/seed with a low of 0.19 mg and a high of 0.38 mg.

Further germination studies concerning the effect of seed coatings on corn showed that EPTC+-coated corn seed (Pioneer 3747) resulted in taller seedlings than uncoated seed when planted in a silt loam soil (Tables V and VI). However, when planted in a soil–sand mixture, there were no significant differnces in the heights or weights of the seedlings from coated or uncoated corn (Tables V–VII). In all studies, seedling emergence was delayed 2 days when coated, with or without herbicide. Subsequent growth was sufficient to compensate for the delay caused by the coatings.

The corn varieties DeKalb XL72aa and XL55a differed greatly in their susceptibilities to injury from EPTC (Table VIII). The XL55a was very sensitive to EPTC. Pioneer 3747 appeared to be comparable to DeKalb XL72aa as to EPTC insensitivity.

Where corn was grown with giant foxtail, seed coatings of EPTC and EPTC+ resulted in decreases in foxtail numbers and heights (Tables V–VIII). Significant reduction of foxtail heights of up to 50% were observed as the levels of EPTC in the coating approached 0.3 mg/corn seed. Decreases in height were greater in coarser textured soil (soil–sand mixture) than in finer textured soil. This tends to confirm the studies in the artificial growth medium (peat–vermiculite mixture) where control of oat seedling growth (indicator crop) was highly effective. These data indicate that corn coated with EPTC and EPTC+ can significantly reduce weed numbers and growth. For the coated corn seeds to be effective for weed control under field conditions where fine-textured soils are involved, higher rates of EPTC and/or EPTC+ will be required and corn varieties that can tolerate these higher levels of EPTC must be used.

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Phenolics, Fiber, and Fiber Digestibility in Bird Resistant and Non Bird Resistant Sorghum Grain

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Differences between bird resistant (BR) and non bird resistant (NBR) sorghum grain in content of fiber and phenolics and relationships among phenolics, fiber, fiber digestibility, and inhibition of fungal cellulase were determined. Two methods for determining neutral-detergent fiber (NDF) were compared. The amylase procedure gave higher NDF values than the urea/amylase procedure. This difference was reflected in lower content of insoluble procyanidins in NDF prepared by the urea/amylase procedure. A newer method based on precipitation of soluble phenolics with ytterbium acetate was highly correlated with the vanillin HCl method. All phenolic components were significantly and negatively correlated with fiber digestibility. There was an inverse relationship between soluble phenolics and insoluble procyanidins in BR varieties. Measurement of soluble phenolics may give incomplete analysis of inhibitory phenolics. Measurements of insoluble procyanidins and/or lignin should be included in studies on the nutritive value of sorghum grain.

Sorghum is an important crop in the semiarid areas of Africa where birds are a major pest (Bullard and York, 1985). Bird resistance is related to the presence of procyanidins in the grain (Gupta and Haslam, 1980), and sorghum improvement programs are selecting bird resistant varieties. However, procyanidins in sorghum decrease nutritive value by complexing protein, carbohydrates, and minerals (Butler, 1982).

Soluble procyanidins are measured by the vanillin/HCl method (Price et al., 1978; Gupta and Haslam, 1980). A new gravimetric method for measuring soluble phenolics by precipitation with ytterbium acetate has been developed (Reed et al., 1985). This study applies the method to sorghum grain and compares it to the vanillin/HCl method.

Sorghums have been grouped on the basis of content and solubility of procyanidins (Price et al., 1978). Group I sorghums are non bird resistant and contain low quantities of vanillin-reactive phenolics. Group III sorghums are bird resistant and contain vanillin-reactive procyanidins that are soluble in methanol. Group II sorghums are intermediate in bird resistance and contain vanillin-reactive procyanidins that are soluble in acidic methanol. In plant materials that contain proanthocyanidins, a large portion can be insoluble in neutral–aqueous–organic solvents (Bate-Smith, 1975). Insoluble proanthocyanidins are present in neutral-detergent fiber (NDF) and are negatively correlated with NDF digestibility (Reed, 1986). This study also determines relationships among soluble phenolics, soluble and insoluble procyanidins, fiber, and fiber digestibility in sorghum grain.

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MATERIALS AND METHODS

Samples and Sample Preparation. Seventeen bird resistant (BR) and seven non bird resistant (NBR) sorghum varieties were grown at Debre Zeit, Ethiopia (1900 m), in a complete randomized block design with four plots (six rows, 5 m long, 75 m between rows) for each variety. Characteristics of the sorghum varieties have been reported elsewhere (Reed et al., 1987). Diammonium phosphate (100 kg ha^{-1}) was applied at planting, and urea (100 kg ha^{-1}) was applied at boot stage. Panicles from four post-ripe plants from each plot were harvested and combined, and the grain was separated by hand and ground

