Tetrazolium Testing Handbook

Contribution No. 29

To the *Handbook on Seed Testing*

Prepared by

The Tetrazolium Subcommittee

of the

Association of Official Seed Analysts

Jack Peters, Editor
Bill Lanham, Illustrator

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Dedication

This handbook is dedicated to the memory of Philena Heckert,
a botanist, seed analyst, and colleague with the Federal Seed Laboratory.
Her diligence and hard work were a source of inspiration
for the completion of this seed testing resource.

Updated 2001: v, 7, 18, Cactaceae, Cucurbitaceae, Cupressaceae, Lamiaceae, Malvaceae, Poaceae II, Tiliaceae
Index A and Index B: addition of *Cynodon*, *Cucumis* and *Nassella*. Entire lab reference section.
Bibliography corrections: on Abdul... page and Throneberry... page.

Updated 8/2002: iv, v, 3, 4, Amaranthaceae, Apiaceae, Poaceae I, Poaceae II, Poaceae IV (new), Lab references.,
Index A and Index B: addtion of *Petroselinum*

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Acknowledgements

The preparation of this handbook began in earnest in the early 1990's
by the AOSA Tetrazolium Subcommittee members
who compiled the information.

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The following pages of tetrazolium testing principles and procedures (by plant family) represent the combined work and collaborative effort of many seed analysts of the *Association of Official Seed Analysts* and the *Society of Commercial Seed Technologists*. I extend a sincere debt of gratitude to all those individuals, seed laboratories, and seed companies who contributed to this effort.

Thank you.
Jack Peters, Editor

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Direct your questions or comments about the contents of this handbook to the AOSA Tetrazolium Subcommittee (members listed on the AOSA website) or the appropriate laboratory references listed for each family. Newly revised pages and procedures for submitting changes and additions are also available at www.aosaseed.com

PREFACE

This handbook has been the result of several years of collaboration by many seed analysts in the *Society of Commercial Seed Technologists* and the *Association of Official Seed Analysts*. Many are listed in the acknowledgements. While it has taken many years to develop this edition, the handbook is by no means complete. Additional procedures for plant families not listed in this handbook may be added in future editions.

The intent of the handbook is to offer guidelines and methodologies in tetrazolium testing. The ultimate goal is to provide uniformity in tetrazolium seed testing, with regard to procedures and TZ staining evaluation. Illustrations in the handbook are used to describe seed/embryo morphology, preparation/cutting techniques, and TZ staining patterns. A bibliography at the end of the handbook lists references associated with tetrazolium seed testing.

The handbook's notebook format is intended to encourage further refinement and experimentation with the TZ methods and techniques. Ample space for notes allows analysts to personalize the instructions. Part II is unpaginated to allow easy updates and additions of plant family procedures. It is the committee's hope that analysts will continue to share experiences and improve the handbook by submitting suggested changes to the committee. Periodic additions and changes are the best way to ensure that the handbook will continue to meet the needs of analysts.

Furrows be glad, though earth is bare —
one more seed is planted there.
Give up your strength the seed to nourish —
that in course the flower may flourish.

Besançon Carol

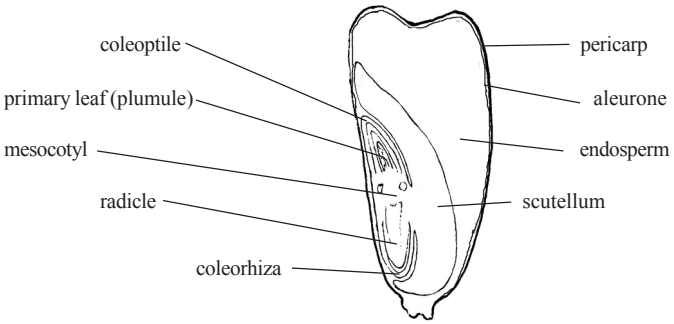
Over the years, TZ test procedures have been greatly improved and refined. Currently, the status and acceptance of the TZ test varies from state to state and country to country. TZ tests are accepted in some states for labeling (analysis tag) on specific species. Some states also allow certification tagging of a seed lot based on viability information supplied by a TZ test. See federal, state, and international seed laws for specific details on TZ test acceptance as a viability indicator.

4. CLASSIFICATION AND STRUCTURE

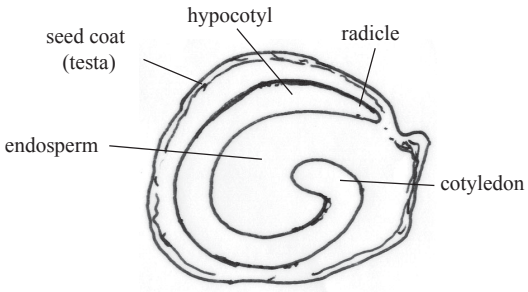
The Tetrazolium Handbook procedures have been categorized by plant family and arranged in a similar fashion to the AOSA *Seedling Evaluation Handbook, Contribution No. 35*. Knowledge of the embryo structure and the seed tissues essential to development of a normal seedling are the foundation for developing skill in tetrazolium testing. The taxonomic group to which the parent plant belongs provides information about its seed anatomy. Seed plants are either Angiosperms (flowering plants)—seed encased in an ovary, or Gymnosperms (naked-seed-bearing plants)—seed not encased in an ovary. Information concerning similarities and differences of embryonic structures can be organized by the separation of seed into five categories:

4.1 Monocotyledon (single modified cotyledon or scutellum)

4.1.1 Simple embryonic axis with scutellum and endosperm (Figure 2 -- corn)

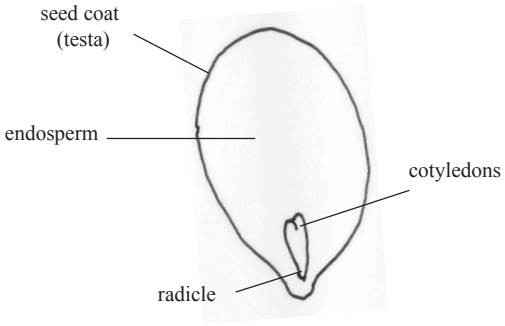


4.1.2 Elongated, single cotyledon embryo and endosperm (Figure 3 -- onion)

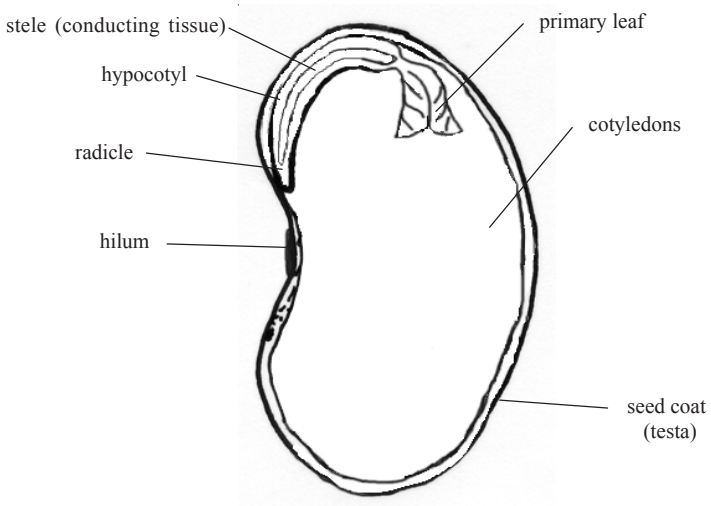


4.2 Dicotyledon (two cotyledons)

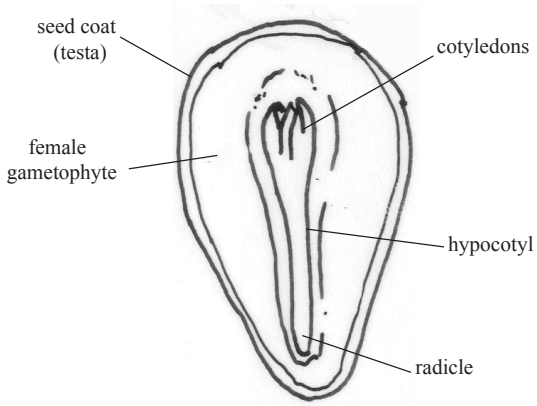
4.2.1 Low level embryonic differentiation (Figure 4 -- columbine)



4.2.2 High level embryonic differentiation (Figure 5 -- garden bean)



4.3 Gymnosperm Two or more cotyledons (Figure 6 -- pine)



Latin names for plant families usually end in ‘aceae’; however, there are eight families that were named before the standardization of botanical nomenclature, for which two names therefore exist. While older, traditional names are still valid, the AOSA has elected to adopt the form with the standard ‘aceae’ endings. The eight families and their synonyms are as follows:

Apiaceae = Umbelliferae
Arecaceae = Palmae
Asteraceae = Compositae
Brassicaceae = Cruciferae
Clusiaceae = Guttiferae
Fabaceae = Leguminosae
Lamiaceae = Labiatae
Poaceae = Gramineae

In referring to a plant or seed, either the common name or the scientific binomial name (genus/species) may be used. The generic nomenclature used in this handbook follows the guidelines of the *Uniform Classification of Weed and Crop Seeds, Contribution No. 25.*

FAMILY: AMARANTHACEAE

Genera: *Amaranthus, Celosia, Gomphrena*

Morphology

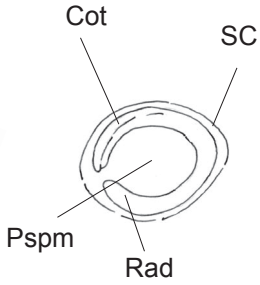
1. PRECONDITIONING:

METHOD	TIME (hrs)	TEMP (°C)
imbibe on moist blotters, filter paper or paper towels	overnight	20-25

.

(side view)

Fig 1 External



(x-section view)

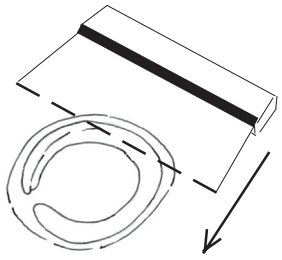
Fig 2 Embryo

Notes: Seeds can become moldy very rapidly. Keep blotters slightly on dry side.

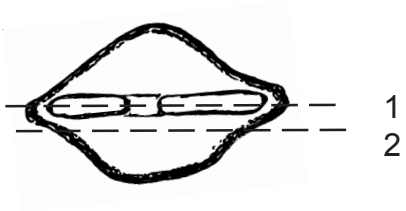
2. PREPARATION & STAINING:

METHOD	TZ Conc(%)	TIME (hrs)	TEMP (°C)
1. with seed on edge, bisect longitudinally	0.1	overnight	20-25
2. with seed on edge, cut a thin slice off one face	1.0	6-18	30-35

Notes: Some seed may take longer to stain (up to 24hrs) in TZ solution



(x-section view)



(side view)

Fig 3 Preparation method

FAMILY: AMARANTHACEAE

Post Staining Notes: None.

3. EVALUATION:

VIABLE (NORMAL STAINING)
- entire embryo evenly stained
- slight radicle damage is acceptable
- perisperm does not stain

NON-VIABLE (ABNORMAL OR NO STAINING)
- any essential part of embryo unstained
- bruised (dark colored) embryo areas

OTHER TISSUE/NOTES
If seed coat is mechanically damaged, bruising of embryo may occur.

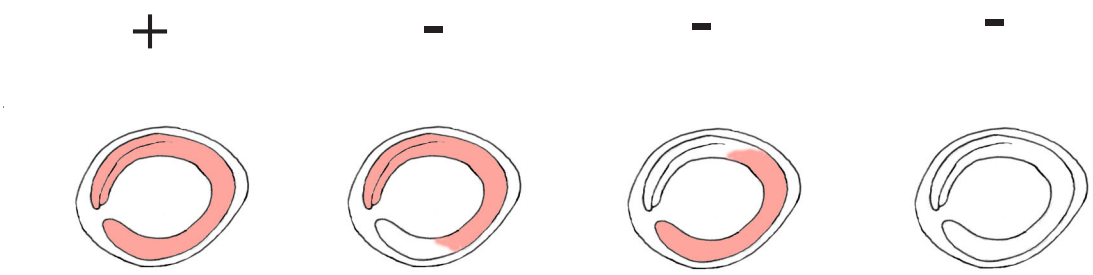


Fig 4 Seed stain evaluation

REFERENCES: 1, 2, 11

FAMILY: APIACEAE

Genera: ***(I)*** ***Anthriscus, Apium, Carum, Coriandrum, Cuminum, Daucus, Petroselinum***

(II) ***Anethum, Pastinaca***

Morphology

1. PRECONDITIONING:

METHOD	TIME (hrs)	TEMP (°C
(I) & *(II)* imbibe on moist paper towels	16	20-25

Fig 1 External

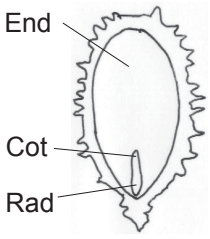
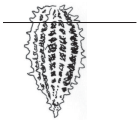


Fig 2 Embryo

Notes: For TZ tests other than those done at the end of a germination test, a longer preconditioning time may be needed. If deep dormancy is suspected, prepare seed with GA_3 prior to staining (see sections 6.3 and 8.3.2).



clip line for GA_3 preconditioning

2. PREPARATION & STAINING:

METHOD	TZ Conc(%)	TIME (hrs)	TEMP (°C)
1. *(I)* cut longitudinally, a thin slice off edge of seed or bisect longitudinally leaving seed intact at distal end	1.0	overnight	20
2. *(II)* cut laterally above embryo	1.0	3-6	30-35

Notes:

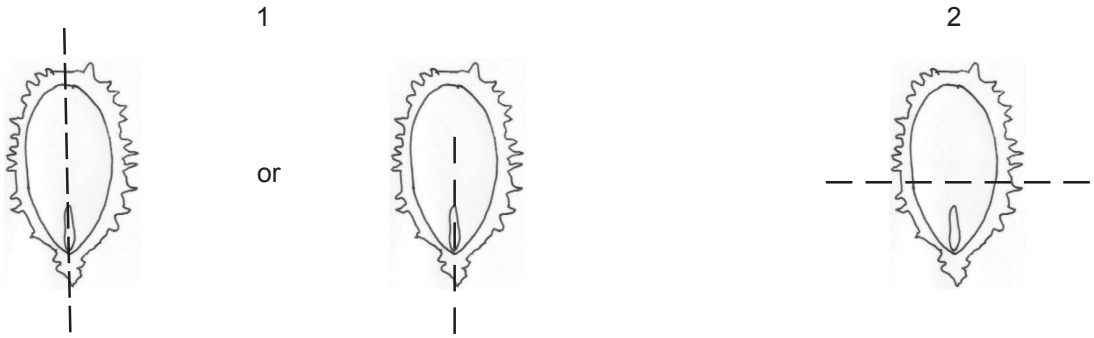


Fig 3 Preparation method

2002

FAMILY: APIACEAE

Post Staining Notes: *(I)* Cut longitudinally, completely through embryo.
(II) Clear with glycerol or lactic acid for 0.5 to one hour at 35° C.

3. EVALUATION:

VIABLE (NORMAL STAINING)
- entire embryo evenly stained
- entire embryo lightly stained is acceptable
- endosperm completely stained

NON-VIABLE (ABNORMAL OR NO STAINING)
- no embryo present
- any essential part of embryo unstained
- watery, flaccid embryo
- endosperm partially or completely unstained
- brown colored embryo, due to field condition or production problem

OTHER TISSUE/NOTES
(I) Seed unit may be either a schizocarp or mericarp (see section 15.1.3.3). Only one embryo must be evaluated as normal in order for entire seed unit to be considered viable. Various methods may be used to ensure that seed units with multiple embryos are kept together.

If turgid, unstained embryos are observed, retest by clipping the distal end and preconditioning with GA_3 (see sections 6.3 and 8.3.2).

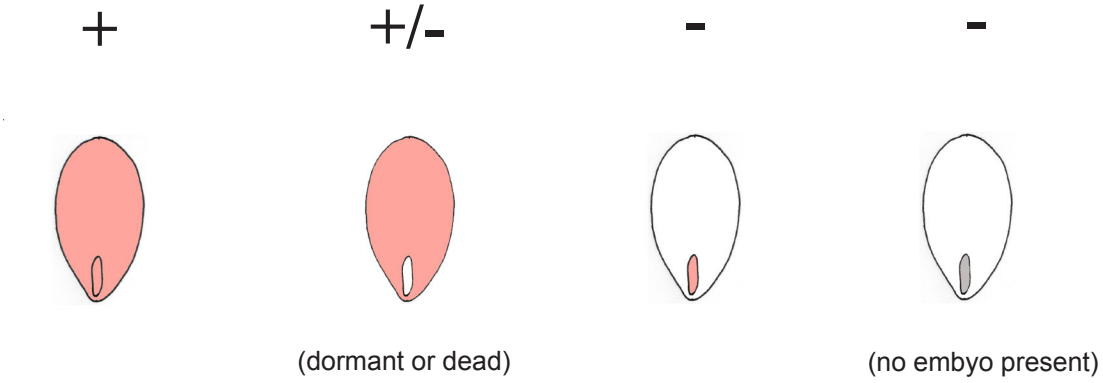


Fig 4 Seed stain evaluation

REFERENCES: 1, 2, 3, 5, 7

FAMILY: POACEAE I (Grass Family I - Cereals except *Sorghum*)

Genera: *Avena, Hordeum, Oryza, Secale, Triticum, Zea*

1. PRECONDITIONING:

METHOD	TIME (hrs)	TEMP (°C)
imbibe on moist rolled paper towels	16-48	20-25
soak in beaker of water	overnight	20-25

Morphology

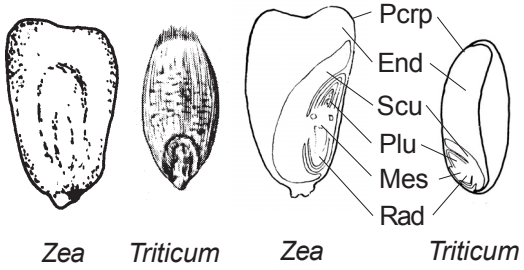


Fig 1 External Fig 2 Embryo

Notes: Endosperm imbibition is slower than radicle/plumule imbibition. Some *Zea* or *Oryza* endosperm may take up to 48 hours to completely soften. If the scutellum, plumule, radicle, and most of the endosperm is softened, seeds may be bisected before complete endosperm imbibition since endosperm tissue is nonliving and will not affect evaluation.

2. PREPARATION & STAINING:

METHOD	TZ Conc(%)	TIME (hrs)	TEMP (°C)
bisect longitudinally through embryo and retain half for staining or leave seed intact at distal end	0.1-0.5	1-2	20-25

Notes:

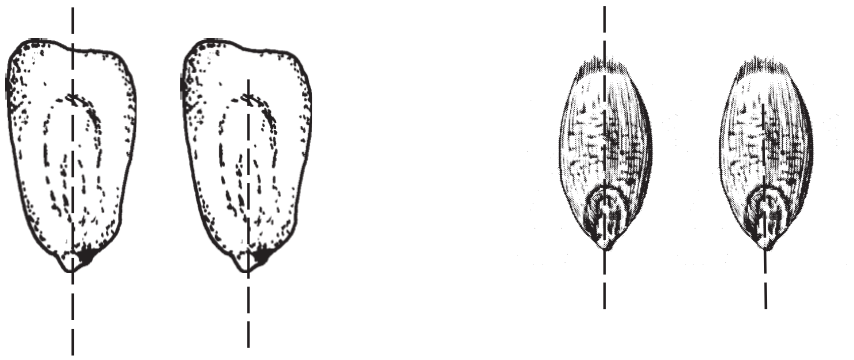


Fig 3 Preparation method

FAMILY: POACEAE I

Post Staining Notes: None; or if seed halves are attached, bisect longitudinally

3. EVALUATION:

VIABLE (NORMAL STAINING)

- at least one-fourth of radicle stained near mesocotyl
- embryo axis completely stained
- plumule completely stained
- endosperm is non-living and will not stain
- no more than a third of scutellum unstained at either end
- a thin, white-colored, superficial layer over scutellum (see sections 14.2 and 15.1.3)
- mechanical damage not affecting essential parts of embryo
- point of attachment of embryo axis to scutellum stained
- coleoptile completely stained

NON-VIABLE (ABNORMAL OR NO STAINING)

- more than three-fourths of radicle unstained (begin measurement from tip and move towards mesocotyl)
- embryo axis less than completely stained
- plumule less than completely stained
- more than a third of scutellum unstained at either end
- mechanical damage affecting essential parts of embryo
- point of attachment of embryo axis to scutellum unstained
- coleoptile less than completely stained

OTHER TISSUE/NOTES

Weak/damaged tissue will stain dark red and frost-damaged tissue will stain light in comparison to normal staining pattern.

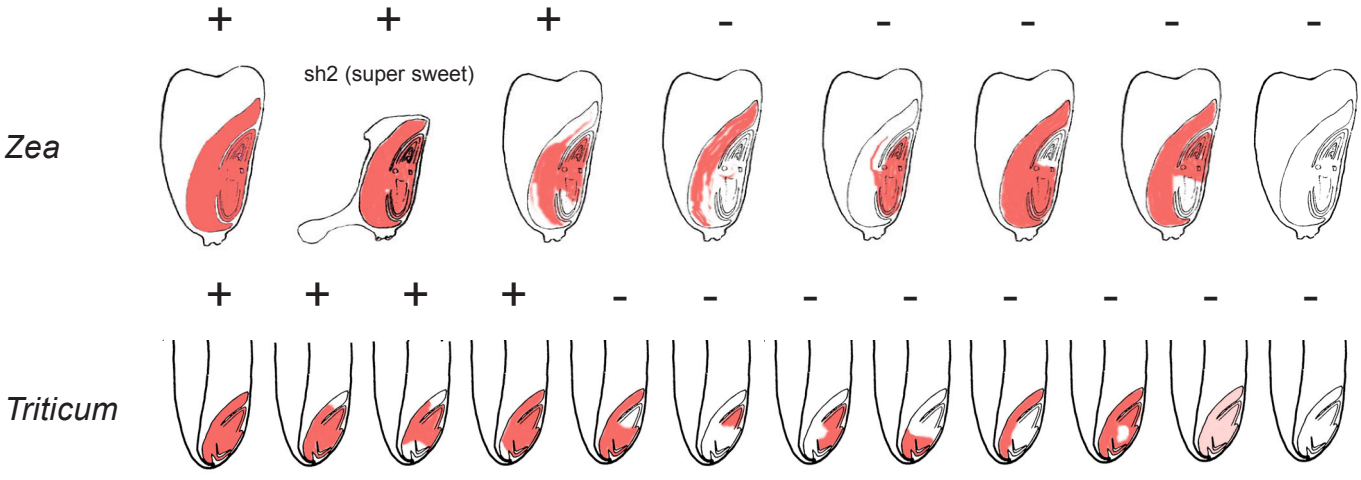


Fig 4 Seed stain evaluation

REFERENCES: 1, 2, 3, 4, 5, 6, 9, 10

FAMILY: POACEAE II (Grass Family II - Small grasses)

Genera: *Achnatherum (syn. Oryzopsis), Agropyron, Agrostis, Bouteloua (see Poaceae III for B. curtipendula), Bromus, Calamagrostis, Cynodon, Dactylis, Elytrigia, Elymus, Eragrostis, Eremochloa, Eriochloa, Festuca, Hilaria, Leptochloa, Leymus, Lolium, Nasella, Panicum, Pascopyrum, Paspalum, Piptatherum (syn. Oryzopsis),Poa, Puccinellia, Schismus, Schizachyrium, Sorghastrum, Sporobolus, Stipa, Zoysia*

1. PRECONDITIONING:

METHOD	TIME (hrs)	TEMP (°C)
1. (larger seed) soak in beaker of water	overnight	20-25
2. (small seed) imbibe on moist blotters, filter paper, or paper towels	overnight	20-25

Morphology

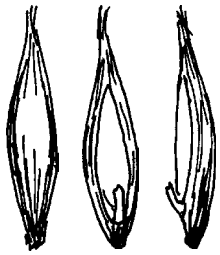


Fig 1 External

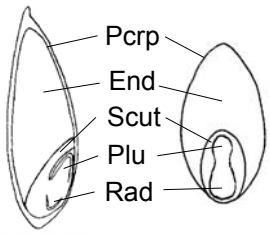


Fig 2 Embryo

Notes: Seed with soft caryopsis (*Dactylis)* do not need a preconditioning step and can be cut dry.

2. PREPARATION & STAINING:

METHOD	TZ Conc(%)	TIME (hrs)	TEMP (°C)
1. (large seed) bisect longitudinally through embryo and retain half for staining or leave seed intact at distal end	0.1-1.0	overnight	20-30
2. (small seed) cut laterally slightly above embryo or undercut laterally beneath embryo	0.1-1.0	overnight	20-30
3. (small or soft seed) pierce with a needle in central endosperm region	1.0	overnight	20-30

Notes: 1. Small grasses or seeds with a soft caryopsis or bisected seeds may stain more rapidly (4-6 hrs) at 35-40°C.
2. TZ concentration will vary with cutting method and is dependent upon seed size, time, and temperature.
3. Seeds that are pierced may be placed in a vacuum oven at 25 psi for 1 hr to facilitate TZ solution uptake and staining.

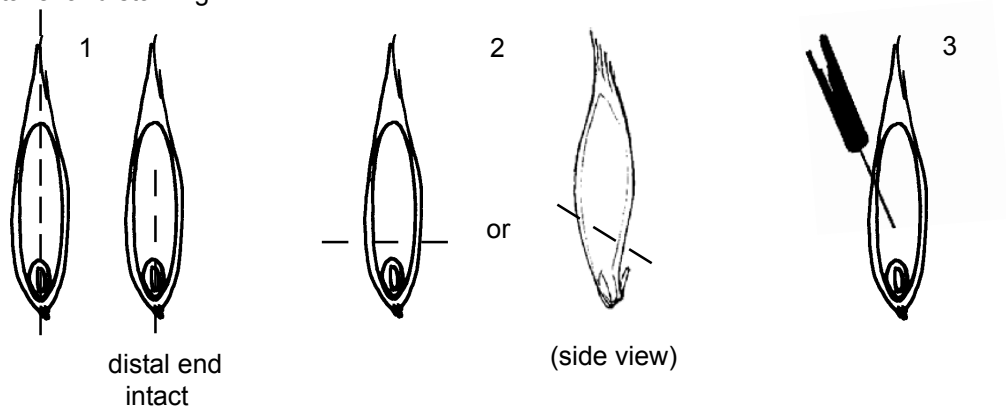


Fig 3 Preparation method

2002

FAMILY: POACEAE II

Post Staining Notes: None for bisected method (1). If seeds cut laterally or pierced (methods 1 or 3) then clear lemma pigmentation with 85% lactic acid for 30 minutes at 25-35°C. If pigmentation remains a problem with microscopic evaluation, bisect seed longitudinally or remove lemma and palea to evaluate.

3. EVALUATION:

VIABLE (NORMAL STAINING)

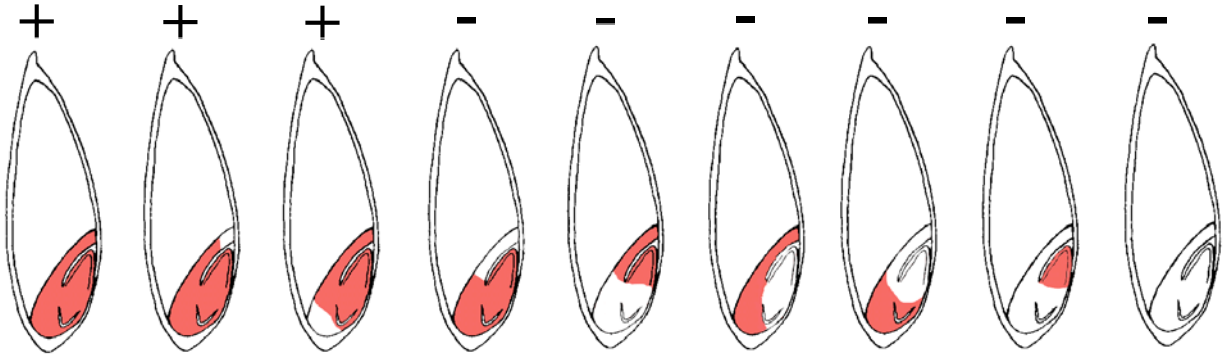
- entire embryo evenly stained
- endosperm will not stain
- unstained outside edge of scutellar region acceptable
- greenish-colored pericarp acceptable if entire embryo stains as normal (particularly over embryonic region)

NON-VIABLE (ABNORMAL OR NO STAINING)

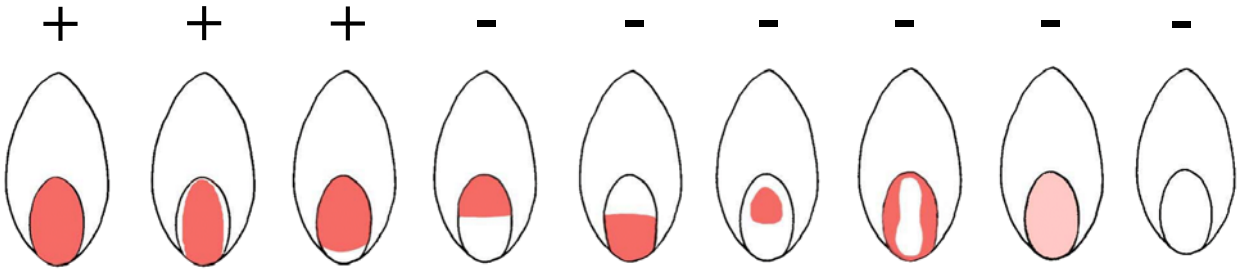
- any essential part of the embryo unstained
- greenish-colored pericarp with off-color or unstained embryo
- mottled or broken embryonic tissue
- soft or flacid stain over embryonic region

OTHER TISSUE/NOTES

Endosperm may have an orange or yellow coloration, but should not stain dark red like embryo. Immature seed which stains light or pale pink with yellow endosperm is considered 'viable' (see sections 15.1.3.2 and 15.1.3.4).



for longitudinally bisected seeds



for pierced or laterally cut seeds

Fig 4 Seed stain evaluation

REFERENCES: 1, 2, 3, 4, 5, 6, 9, 10, 11

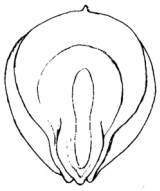
FAMILY: POACEAE IV (Grass Family IV)

Genera: *Sorghum*

1. PRECONDITIONING:

METHOD	TIME (hrs)	TEMP (°C)
imbibe on moist rolled paper towels	overnight	20-25

Morphology



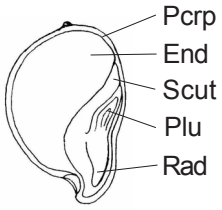


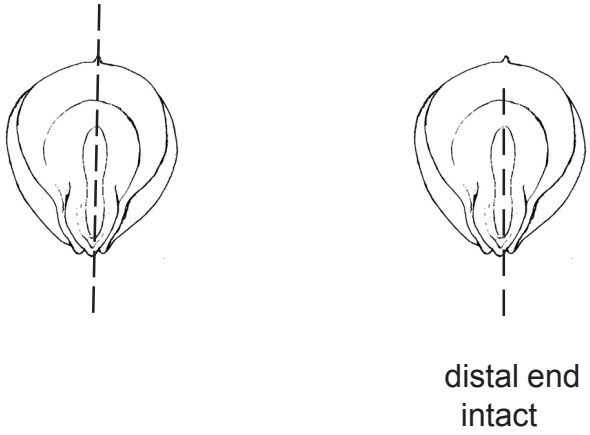
Fig 1 External Fig 2 Embryo

Notes:

2. PREPARATION & STAINING:

METHOD	TZ Conc(%)	TIME (hrs)	TEMP (°C)
bisect longitudinally through embryo and retain half for staining or leave seed intact at distal end	0.1-0.5	1-2	20-25

Notes:



distal end intact

Fig 3 Preparation method

FAMILY: POACEAE IV

Post Staining Notes: None; or if seed halves are attached, bisect longitudinally

3. EVALUATION:

VIABLE (NORMAL STAINING)
- radicle completely stained
- embryo axis completely stained
- plumule completely stained
- endosperm is non-living and will not stain
- no more than a third of scutellum unstained at either end
- a thin, white-colored, superficial layer over scutellum (see sections 14.2 and 15.1.3)
- mechanical damage not affecting essential parts of embryo
- point of attachment of embryo axis to scutellum stained
- coleoptile completely stained

NON-VIABLE (ABNORMAL OR NO STAINING)
- radicle less than completely stained
- embryo axis less than completely stained
- plumule less than completely stained
- more than a third of scutellum unstained at either end
- mechanical damage affecting essential parts of embryo
- point of attachment of embryo axis to scutellum unstained
- coleoptile less than completely stained

OTHER TISSUE/NOTES

Weak/damaged tissue will stain dark red and frost-damaged tissue will stain light in comparison to normal staining pattern. Paliwal, S. et. al., 1990, noted color variations in embryo staining that were attributed to cultivar differences. Variation ranged from bright pink to bright red or brownish red and the differences were not related to seed quality.

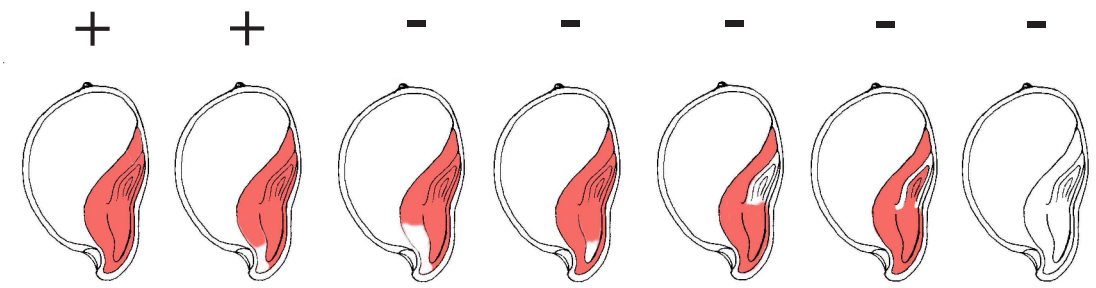


Fig 4 Seed stain evaluation

REFERENCES: 1, 2, 3, 4, 5, 6, 9, 10

INDEX - A
(cross-reference)

Family/Genus

Genus/Family

for common names, species, or classification references, please refer to the AOSA *Uniform Classification of Weed and Crop Seeds, Contribution No. 25* to the *Handbook on Seed Testing*

FAMILY	GENUS
Acanthaceae	*Crossandra*
	Hypoestes
	Justicia
Aceraceae	*Acer*
Agavaceae	*Cordyline*
	Yucca
Aizoaceae	*Dorotheanthus*
	Tetragonia
Amaranthaceae	*Amaranthus*
	Celosia
	Gomphrena
Anacardiaceae	*Rhus*
Apiaceae	*Anethum*
	Anthriscus
	Apium
	Carum
	Coriandrum
	Cuminum
	Daucus
	Pastinaca
	Petroselinum
Apocynaceae	*Catharanthus*
Asclepiadaceae	*Asclepias*
Asteraceae	*Ambrosia*
	Artemisia
	Aster
	Baccharis
	Baileya
	Balsamorhiza
	Carthamus
	Chrysopsis
	Chrysothamnus
	Encelia
	Galinsoga
	Grindeli
	Haplopappus
	Helenium
Asteraceae	*Helianthus*
	Lactuca
	Rudbeckia
	Verbesina
Balsaminaceae	*Impatiens*
Begoniaceae	*Begonia*
Berberidaceae	*Berberis*
	Mahonia
Betulaceae	*Alnus*
	Betula
Bignoniaceae	*Catalpa*
	Chilopsis
	Paulownia
Boraginaceae	*Cynoglossum*
	Heliotropium
	Myosotis
Brassicaceae	*Barbarea*
	Brassica
	Crambe
	Draba
	Eruca
	Lepidium
	Lesquerella
	Physaria
	Raphanus
	Rorippa
	Sinapis
Cactaceae	*Carnegiea*
	Ferocactus
	Lophocereus
	Opuntia
	Pachycereus
Campanulaceae	*Campanula*
	Platycodon
Capparaceae	*Cleome*

GENUS	FAMILY
Clarkia	Onagraceae
Clematis	Ranunculaceae
Cleome	Capparaceae
Clinopodium	Lamiaceae
Cobaea	Polemoniaceae
Coleus	Laminaceae
Collinsia	Scrophulariaceae
Consolida	Ranunculaceae
Cordyline	Agavaceae
Coriandrum	Apiaceae
Cornus	Cornaceae
Cowania	Rosaceae
Crambe	Brassicaceae
Crataegus	Rosaceae
Crossandra	Acanthaceae
Cryptomeria	Taxodiaceae
Cucumis	Cucurbitaceae
Cucurbita	Cucurbitaceae
Cuminum	Apiaceae
Cunninghamia	Taxodiaceae
Cupressus	Cupressaceae
Cyclamen	Primulaceae
Cynodon	Poaceae
Cynoglossum	Boraginaceae
Cyperus	Cyperaceae
Dactylis	Poaceae
Dalea	Fabaceae
Datura	Solanaceae
Daucus	Apiaceae
Delphinium	Ranunculaceae
Desmanthus	Fabaceae
Dianthus	Caryophyllaceae
Dictamnus	Rutaceae
Digitalis	Scrophulariaceae
Diospyros	Ebenaceae
Dorotheanthus	Aizoaceae
Draba	Brassicaceae
Elaeagnus	Elaeagnaceae
Elymus	Poaceae
Elytrigia	Poaceae
Encelia	Asteraceae
Ephedra	Ephedraceae
Epilobium	Onagraceae
Episcia	Gesneriaceae
Eragrostis	Poaceae
Eranthis	Ranunculaceae
Eremochloa	Poaceae
Eriochloa	Poaceae
Eriogonum	Polygonaceae
Erodium	Geraniaceae
Eruca	Brassicaceae
Erythronium	Liliaceae
Eschscholzia	Papaveraceae
Eucalyptus	Myrtaceae
Eugenia	Myrtaceae
Euphorbia	Euphorbiaceae
Eustoma	Gentianaceae
Fagopyrum	Polygonaceae
Fagus	Fagaceae
Fallugia	Rosaceae
Ferocactus	Cactaceae
Festuca	Poaceae
Forestiera	Oleaceae
Fraxinus	Oleaceae
Fuchsia	Onagraceae
Galinsoga	Asteraceae
Gaura	Onagraceae
Gentiana	Gentianaceae
Geranium	Geraniaceae
Gilia	Polemoniaceae
Ginkgo	Ginkgoaceae
Gleditsia	Fabaceae
Glycine	Fabaceae
Godetia	Onagraceae
Gomphrena	Amaranthaceae
Gossypium	Malvaceae
Grevillea	Proteaceae
Grindelia	Asteraceae
Gymnocladus	Fabaceae
Gypsophila	Caryophyllaceae
Hamamelis	Hamamelidaceae
Haplopappus	Asteraceae
Hedysarum	Fabaceae
Helenium	Asteraceae
Helianthus	Asteraceae
Helianthemum	Cistaceae
Heliotropium	Boraginaceae
Helleborus	Ranunculaceae
Hepatica	Ranunculaceae
Hibiscus	Malvaceae
Hilaria	Poaceae
Holodiscus	Rosaceae
Hordeum	Poaceae
Hunnemannia	Papaveraceae
Hypoestes	Acanthaceae
Hyssopsus	Laminaceae
Impatiens	Balsaminaceae

GENUS	FAMILY
Indigofera	Fabaceae
Ipomoea	Convolvulaceae
Iris	Iridaceae
Juglans	Juglandaceae
Juncus	Juncaceae
Juniperus	Cupressaceae
Justicia	Acanthaceae
Kalanchoe	Crassulaceae
Kniphofia	Liliaceae
Kochia	Chenopodiaceae
Krascheninnikovia	Chenopodiaceae
Kummerowia	Fabaceae
Lactuca	Asteraceae
Lagenaria	Cucurbitaceae
Lantana	Verbenaceae
Larix	Pinaceae
Larrea	Zygophyllaceae
Lathyrus	Fabaceae
Lens	Fabaceae
Lepidium	Brassicaceae
Leptochloa	Poaceae
Lesquerella	Brassicaceae
Leucaena	Fabaceae
Leymus	Poaceae
Lilium	Liliaceae
Limnanthes	Limnanthaceae
Limonium	Plumbaginaceae
Linanthus	Polemoniaceae
Linaria	Scrophulariaceae
Linum	Linaceae
Liquidambar	Hamamelidaceae
Liriodendron	Magnoliaceae
Lisianthus	Gentianaceae
Littorella	Plantaginaceae
Lolium	Poaceae
Lonicera	Caprifoliaceae
Lophocereus	Cactaceae
Lupinus	Fabaceae
Lychnis	Caryophyllaceae
Lycopersicon	Solanaceae
Magnolia	Magnoliaceae
Mahonia	Berberidaceae
Malus	Rosaceae
Malva	Malvaceae
Medicago	Fabaceae
Melilotus	Fabaceae
Melissa	Lamiaceae
Mentha	Lamiaceae
Metasequoia	Taxodiaceae
Mimulus	Scrophulariaceae
Mirabilis	Nyctaginaceae
Monarda	Lamiaceae
Myosotis	Boraginaceae
Nassella	Poaceae
Nemesia	Scrophulariaceae
Nemophila	Hydrophyllaceae
Nepeta	Lamiaceae
Nicotiana	Solanaceae
Nierembergia	Solanaceae
Nigella	Ranunculaceae
Nyssa	Nyssaceae
Ocimum	Lamiaceae
Oenothera	Onagraceae
Opuntia	Cactaceae
Origanum	Lamiaceae
Orthocarpus	Scrophulariaceae
Oxybaphus	Nyctaginaceae
Pachycereus	Cactaceae
Panicum	Poaceae
Papaver	Papaveraceae
Parthenocissus	Vitaceae
Pascopyrum	Poaceae
Paspalum	Poaceae
Passiflora	Passifloraceae
Pastinaca	Apiaceae
Paulownia	Bignoniaceae
Pelargonium	Geraniaceae
Penstemon	Scrophulariaceae
Petroselinum	Apiaceae
Petunia	Solanaceae
Phacelia	Hydrophyllaceae
Phaseolus	Fabaceae
Phlox	Polemoniaceae
Physalis	Solanaceae
Physaria	Brassicaceae
Picea	Pinaceae
Pinus	Pinaceae
Piptatherum *(syn. Oryzopsis)*	Poaceae
Pisum	Fabaceae
Plantago	Plantaginaceae
Platanus	Platanaceae
Platycladus	Cupressaceae
Platycodon	Campanulaceae
Plumbago	Plumbaginaceae
Poa	Poaceae

Laboratory References

Seed laboratories that submitted or contributed to the Handbook's TZ testing procedures

2002

The following are the seed testing laboratories that provided information and testing methods for this handbook. The laboratory reference numbers listed below and appearing under 'References' on each TZ procedure page identify laboratories that are resources for analysts.

[p=phone; f=fax; e=email; c=contact person]

Lab reference No.	Lab/company	Address/telephone/fax/email/contact
1	**STA Laboratories, Inc.**	PO Box 1257 821 Vista View Dr. Longmont, CO. 80502-1257 p) (303) 651-6417 f) (303) 772-4003 e) barbara.atkins@stalabs.com c) Barbara Atkins, RST
2	**Oregon State Seed Lab**	OSU Corvallis, OR. 97331 p) (541) 737-4464 f) (541) 737-2126 e) Sabry.Elias@orst.edu c) Sabry Elias, PhD
3	**Ransom Seed Laboratory**	P.O. Box 300 Carpinteria, CA. 93014-0300 p) (805) 684-3427 f) (805) 684-4157 e) ransomSL@silcom.com c) Nancy Vivrette, PhD, RST
4	**Utah State Seed Lab**	Utah Dept. of Agriculture & Food 350 N. Redwood Rd. Box 146500 Salt Lake City, UT. 84114-6500 p) (801) 538-7182 f) (801) 538-7189 e) sakagi@utah.gov c) Stan Akagi
5	**USDA/ARS National Center for Genetic Resources Preservation**	1111 S. Mason St. Ft. Collins, CO. 80521-4500 p) (970) 495-3200 f) (970) 221-1427 e) almiller@lamar.colostate.edu c) Annette Miller, RST

Lab reference No.	Lab/company	Address/telephone/fax/email/contact
6	**California State Seed Lab**	California Dept. of Food and Ag. Plant Pest Diagnostics Center 3294 Meadowview Rd. Sacramento, CA. 95832-1448 p) (916) 262-1138 f) (916) 262-1190 e) mstephen@cdfa.ca.gov c) Marian Stephenson, PhD, RST
7	**Precision Seed Testing**	5380 Vivian St. Arvada, CO. 80002 p) (303) 431-7333 f) (303) 467-7886 e) lab@applewoodseed.com c) previous contact Jane Hall, RST - No longer available for consultation
8	**USDA/FS National Tree Seed Lab**	USDA - Forest Service 5156 Riggens Mill Rd. Rt. 1, Box 182-B Dry Branch, GA. 31020-9696 p) (478) 751-3551 f) (478) 751-4135 e) wjohnson03@fs.fed.us c) Gary Johnson / Victor Vankus
9	**Iowa State Seed Lab**	128A - Seed Science Center Ames, IA. 50011-3228 p) (515) 294-6826 f) (512) 294-2014 e) curry@iastate.edu c) Dan Curry
10	**Colorado State Seed Lab**	Plant Science Bldg. Colorado State University Fort Collins, CO. 80523 p) (303) 491-6406 f) (303) 491-1173 e) mmilhous@lamar.colostate.edu c) Marilyn Milhous, RST
11	**New Mexico State Seed Lab**	P.O. Box 30005, Dept. 3190 Las Cruces, NM. 88003-3407 p) (505) 646-3407 f) (505) 646-5977 e) mgill@nmda-bubba.nmsu.edu c) Mike Gill

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