To the Graduate Council:

I am submitting herewith a dissertation written by A. David Sime entitled "Systematic Studies With Selected Members of the Genus *Melanotus* (Strophariaceae, Agaricales)". I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Botany.

Ronald H. Petersen, Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:

Interim Vice Provost and
Dean of The Graduate School

SYSTEMATIC STUDIES WITH SELECTED MEMBERS OF THE GENUS *MELANOTUS* (STROPHARIACEAE, AGARICALES)

A Dissertation

Presented for the

Doctor of Philosophy

Degree

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A. David Sime

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ABSTRACT

The genus *Melanotus* represents a heterogeneous assemblage of brown to purple-brown-spored pleurotoid mushrooms that are either lignicolous or graminicolous, and which exhibit a primarily amphi-mesothermal, temperate forest distribution with a secondarily circumtropical range distribution. In traditional literature, systematics of the genus were based primarily on macro- and micromorphological characters of basidiomata. Reliance on a relatively small set of morphological characters in the circumscription of taxa within *Melanotus* has resulted in a species concept that does not reflect genetically similar units.

In order to develop a better understanding of the genetic relationships within *Melanotus*, this study has: 1) re-examined traditional morphological characters; 2) analyzed previously unexamined morphological characters; 3) determined the mating systems operating within and between selected taxa; 4) identified discrete intersterility groups; 5) incorporated the use of an arbitrary PCR fingerprinting technique (DAF) to discriminate among and between selected taxa; and 6) included examination of type specimens in order to determine the correct application of names.

A phenetic analysis of the morphological data indicates that the circumscription of morphological variation within *Melanotus* is limited to a few previously unreported macro- and micromorphological characteristics. Most morphological characters traditionally used to segregate infrageneric taxa into discrete units were found to significantly overlap. The application of a singular morphospecies concept alone is not advocated within *Melanotus*.

Mating systems were determined for 23 collections within *Melanotus*, revealing a mixture of mating systems. Three intersterility groups to which names could be applied were identified. The use of a biological species concept in the systematics of the genus *Melanotus* is considered taxonomically informative, and advocated.

DNA-amplification fingerprinting data confirm that taxa within *Melanotus* appear to be separable based on: 1) placement within a common intersterility group; and to a lesser degree; 2) geographic proximity of collections; and 3) substratum preference. The use of DAF may be of limited value in the interspecific taxonomy of the genus, and is recommended only for placement of isolates that have been previously identified using a biological species concept.

The results of this study indicate that only through the use of multiple data sets (i.e., morphology, mating, molecular) can natural groups within *Melanotus* be identified. Several names previously used within these identified natural groups of *Melanotus* are considered synonyms of the priorable names within two groups: *M. alpiniae* and *M. horizontalis*, while collections of *M. defraudatus* also appear to represent a natural group.

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I. INTRODUCTION

A. Taxonomic History

Melanotus was first recognized (Patouillard, 1900) for a group of dark-spored, pleurotoid agarics placed in the genus *Agaricus* by Fries (1821; 1838) and Bulliard (1787-8). Many taxa now recognized as belonging to *Melanotus* were previously placed in other genera such as *Crepidotus*, *Claudopus*, and *Phaeomarasmius* (Singer, 1952, 1973, 1975, 1977).

Melanotus is characterized by small, pleurotoid, convex mushrooms with a lateral to eccentric stipe; absence of veil remnants; pileipellis a cutis or trichodermium with interwoven, cylindrical hyphal elements with clamp connections and encrusting pigments; hyaline cheilocystidia; and purple-brown spores exhibiting an apical germ pore (Horak, 1977). The etymology of the name *Melanotus* is "dark-ear" (Donk, 1962).

B. Morphological Intergeneric Relationships

Dictated by their habit and habitat, most species of *Melanotus* have been published under either *Crepidotus* or *Claudopus*. *Crepidotus* spores however, are either globose or elliptical, typically ornamented, with no germ pore, while *Claudopus* spores are angular in all views, with no germ pore. Macroscopically, *Melanotus* taxa may also be confused with *Pleuroflammula*, *Phaeomarasmius*, and *Pyrrhoglossum*. *Pleuroflammula* differs by its brown spore print, spores that possess an oblique germ pore or none, and water-soluble yellow pigment. *Phaeomarasmius* basidiomata have a

scaly cap, and rather large spores (>11 µm in length) while *Pyrrhoglossum* has verrucose spores.

Within *Melanotus*, substratum and microscopic characters (Horak, 1977; Watling and Gregory, 1987; Singer, 1973, 1989) have traditionally circumscribed species. Basidiospore ranges for many taxa significantly overlap (Table 1). Likewise, substratum characters do not provide any insight to infraspecific relationships. Within the spore-range groups, taxa may be found on gymnosperm, angiosperm, or monocotyledon substrata.

Table 1. Outline of the genus *Melanotus* as interpreted by various authors. NA = North America; AA = Australasia, SA = South America; CA = Central America; IA = India; E = Europe; AF= Africa, NG = New Guinea, NC = North Carolina, USA; lvs. = leaf or leaves of plants.

Author, year	Taxon	Spore Range		Locale	Topotype locale	Substratum
		l	w			
Ammirati et. al., 1979	*M. hartiae*	5.0-6	3.7-4.4	NA	Washington, USA	*Picea* timber(mine)
Guzmán and Vergeer, 1978	*M. caricicola*	5.5-7	3.0-4	NA	BritishColumia,Canada.	grass
Horak, 1977	*M. citrispora*	10.0-13	4.0-5	AA	New Zealand	lvs. *Astelia*
Horak, 1977	*M. protractus*	10.5-12.5	9.0-12	AA	Papua, N. G.	*Musa* lvs.
Horak, 1977	*M. vorax*	6.5-8.5	4.0-5	AA	New Zealand	ferns
Horak, 1977	*M. bruchii*	6.0-8	4.5-6	SA	Argentina, Chile	*Chusquea*
Horak, 1977	*M. distinctus*	6.0-7	4.0-5	AA	Papua, N. G.	dicot: rotten wood
Horak, 1977	*M. bambusinus*	6.0-7	4.0-5	AS	Vietnam	bamboo
Horak, 1977	*M. communis*	5.0-7	3.5-4.5	AA	Papua, N. G.	rott-branches
Horak, 1992	*M. defraudatus*	5.0-6	3.0-4	NA	NC,USA	*Carex* sp.
Horak, 1977	*M. alpinae*	5.5-7.5	4.0-5	SA, CA	Brazil	lvs: *Alpinia*, zingiberaceae
Natarajan and Raman, 1983	*M. macrosporus*	9.8-11.2	7.0-8.4	IA	Tamil Nadu	dicot tree trunk
P.D. Orton, 1984	*M. horizontalis*	5.0-7	3.5-4.5	E	Essex, Surrey	beech stump
Pegler, 1977	*M. gelineus*	5.5-7(8)	3-4(5)	AF	Kenya	decomp. twigs

Table 1. (continued).

Redhead and Kroeger, 1984	*M. textilis*	6.0-7	3.5-4.5	NA	BritishColumbia, Canada	fabric, pines
Singer, 1946	*M. flavolivens*	(5)6-7	3.5-5	AA	Bonin Islands	*Cocos* lvs.
Singer, 1946	*M. haematites*	5.5-7	6.7-7.5	AS	Hong Kong	dicot-rotten wood
Singer, 1947	*M subcuneiformis*	7.0-8	5.5	CA	Grenada	*Cocos* husks
Singer, 1947	*M. eccentricus*	5.0-6	3.5-4	CA	Puerto Rico, + Mexico	herbaceous
Singer, 1951	*M. hepatochrous*	5.5-7.5	4-5.5	AA	New Zealand, Tasmania	dicot-rotten wood
Singer, 1952, 1961	*M. cassiacolor*	8.0-11	5.7-7.7	SA	Chile	dicot-rotten wood
Singer, 1973	*M. polylepidis*	4.5-5.5	3-3.5	SA	Argentina	bark *Polylepidis*
Singer, 1955	*M. ridleyi*	5.5-6.5	3.5-4.5	AA	Malaya	ferns
Singer, 1969	*M. patagonicus*	6.0-7(-7.5)	4.0-5	SA	Argentina	wood
Singer, 1973. Moser, 1978	*M. phillipsii*	5.0-6	2.5-3	E, AF	Europe, Morocco	grass, *Scrophularia* stems
Singer, 1977	*M. brevisporus*	5.3-5.8(6.2)	4.4-4.8(5)	SA	Ecuador	dicot wood, decomp.
Singer, 1989	*M. decapitatus*	6.0-7	4.5-5.3	SA	Venezuela	branches
Singer, 1989	*M. dumontii*	6.0-7	4.2-4.6	SA	Columbia	*Chusquea*
Singer, 1989	*M. musacearum*	5.3-7.5	4-5.5	SA ,CA	Brazil, Mexico	*Musa* lvs.
Singer, 1989	*M. heteroloma*	5.2-5.5	4-4.5	SA	Bolivia	dicot: rotten wood
Singer,1946	*M. proteus*	6.0-7	4.0-5	AF	Kenya,South Africa	*Cupressus* wood
Singer,1989	*M. matrisdesi*	5-6.3	4.0-5	SA	Bolivia	monocot

A pervasive systematic problem has been how to separate *Melanotus* from *Psilocybe*. Basidiomata of two genera are extremely similar microscopically, being separated only by the macromorphological character of a central stipe in *Psilocybe* as contrasted to the reduced stipe of basidiomata of *Melanotus*. Horak (1977), Singer (1975), and Romagnesi (1977) questioned whether or not presence and/or placement of the stipe in *Melanotus* was a sufficient criterion on which to separate genera. Horak (1977) further stated that in a single population of *Melanotus* in the same locality on the same host the stipe position could be variable, dependent upon microtopographical position on the substratum. Personal observations have confirmed this in *Melanotus*, where basidiomata fruiting on a decaying log showed a graduation of stipe placement, with centrally stipitate, upright individuals on the upper surface of the log, to eccentric, lateral, or finally effuso-reflexed individuals on the sides and undersurface.

Stipe placement may prove to be an artificial generic criterion in this case. Horak (1977) recommended experimenting under pure culture conditions to determine the relevance of stipe placement in *Melanotus* and *Psilocybe*. It has already been demonstrated that *Melanotus* species will fruit *in vitro* (Newman, 1968; Ammirati et. al., 1979; Sime, unpub. data). Sporocarp ontogeny may be studied under controlled conditions. Watling (1971) demonstrated that under pure culture conditions an isolate of *Psilocybe merdaria* was mutable. Normal basidiomata developed along with forms ranging from laterally stipitate to gastroid. Watling (1971) termed the laterally stipitate form "melanotoid." It was found that the extreme morphological forms could

be subcultured with succeeding generations eventually only expressing the aberrant condition.

Singer (1986) included *Melanotus* in the family Strophariaceae. He divided the Strophariaceae into two subfamilies based on spore print color: subfamily Pholiotoideae shows brown spores while species of the Stropharioideae produced lilac to purple-brown spores. *Melanotus* segregated into subf. Stropharioideae, where *Melanotus* and *Psilocybe* differ from *Stropharia* and *Hypholoma* by the lack of chrysocystidia in the former. Singer (1986) separated *Melanotus* from *Psilocybe* by the central stipe in *Psilocybe*, but (Singer, 1975) made no reference to the absence of pleurocystidia in *Melanotus* as Horak stated (1977; but see Singer , 1951). In a revision of the Strophariaceae, Wasser and Grodzinskaya (1996) offered a one-subfamily concept for the Strophariaceae, based upon evolutionary stable macro-and micro- characters. They felt that "ecological peculiarities" of *Melanotus* did not justify separation at generic rank. However, they did not speculate on what these ecological peculiarities might be. Surely they referred to growth on the sides of substrata. Furthermore, they also felt that *Melanotus* was difficult to separate from *Psilocybe*. The generic concepts of Smith (1979), Kühner (1980) and Noordeloos (1995) treat the Strophariaceae as comprising only two genera, *Psilocybe* and *Pholiota*. *Melanotus* under Noordeloos's (1995) proposed new combinations is a subgenus of *Psilocybe*.

Moncalvo et al (2000) in a report on the phylogeny of the Agaricinae based on nLSU RNA report that members of the family Strophariaceae form a paraphyletic

group. The monophly of the genera *Stropharia*, *Pholiota*, and *Hypholoma* were supported by their analyses, suggesting that Singer's (1986) subfamilies Strophariodeae and Pholiotoideae are not monophyletic. Moncalvo et al's (2000) analysis of the family Strophariaceae only includes seven collections, none as *Melanotus*. Therefore it is uncertian whether 1) *Melanotus* is contaxic with *Psilocybe*; and 2) Moncalvo et al's (2000) analysis of the family Strophariaceae *sensu* Singer (1986) is insufficient due to the small sample size. See Moncalvo et al (2000) for a discussion of how sample size can affect phylogenetic inference.

C. Morphotaxonomic Biogeography

The genus *Melanotus* Patouillard (Strophariaceae, Agaricales, Basidiomycotina) is diagnosed as a group of dark-spored pleurotoid mushrooms that are saprophytic on monocots, herbaceous plants and large tracheophytes. Presently, the genus is represented worldwide by about 33 described names (Table 1). Due to their small basidiome size and infrequent appearance, current reports on distribution are, at best, preliminary.

The northern-most record of a *Melanotus* species is from Sweden for *M. phillipsii*, while in the Southern Hemisphere it is *M. hepatochrous* from Tasmania. The bulk of *Melanotus* taxa occur in broad-leaf evergreen deciduous forests with a typical shrubby understory. The majority of *Melanotus* species have been reported from the neotropics (Singer, 1973; Horak, 1977); Europe and Australasia are second in number of described taxa (Reijnders & Vellinga, 1992, Krieglsteiner, 1984, 1991; Kasparek, 1994; Wilhelm 1998; Kits van Waveren, 1979; Watling and Gregory, 1987; Moser

1978; Horak, 1977) while four taxa have been cited from Africa (Pegler 1977; Pegler 1986; Thumen, 1876; Malençon & Bertault, 1970) one from India (Natarajan & Raman, 1983), and one from Spain (Esteve-Raventós et al., 1996).

The first record of a North American *Melanotus* species north of Mexico was by Ammirati et al (1979) from an underground spruce timber in a gold mine in Ontario. With no subsequent report of this taxon coupled with the type habitat, the distrubution of this taxon remains unclear. A second temperate North American species, *M. caricicola* (Orton) Guzmán, was reported from Ontario and Quebec by Redhead and Malloch (1980) and later from British Columbia (Redhead, 1984). The third documented North American *Melanotus* was by Redhead and Kroeger (1984), and Redhead (1989) for *M. textilis*, which fruits on wood and rotting fabrics in British Columbia and adjacent US Pacific Northwest. Horak et al. (1990) were the latest to report on a North American taxon, with *M. defraudatus* inhabiting *Carex* sp. stems in North Carolina.

D. Ecology

Many species are known only from their type locality, so knowledge about their ecology is still rather poor. Approximately 60% of *Melanotus* species have been reported as saproptrophic on monocotyledonous plants. Apparently less than 2% destroy fabrics. The remainder are also saprophytic, but on decaying angiosperm and gymnosperm wood. In the field, *Melanotus* mycelium produces a soft to spongy white rot, depending on local moisture conditions (Sime, unpub. data). White-rot fungi typically produce a battery of phenoloxidase enzymes to digest lignin. Petersen

(1992) has confirmed this by the presence of laccase and tyrosinase in *M. eccentricus*; while Horak et al. (1990) also reported *M. defraudatus* as positive for laccase and tyrosinase.

It remains to be seen whether or not *Melanotus* can exist as a facultative parasite. In a report on range extension for *M. proteus* in Britain, Redfern (1991) provided some evidence that *M. proteus* may act as a primary decomposer of wounded *Picea* trees. This observation has been confirmed for wounded *Picea* trees, and *Sequoia sempervirens* slash in California (Sime, unpub. data). Presumably due to its rapid life cycle, Redfern (1991) further advocated the use of *M. proteus* as a biological control agent against *Heterobasidion annosum*, a common root-rot pathogen of trees. While in the field in Argentina I have observed *Melanotus* species fruiting directly on exposed cambial tissues of young *Nothofagus* saplings, in exposed wounds. In this instance it would appear that *Melanotus* might have the capacity to invade living tissues. Currah and Zelmer (1992) in a report on endophytic fungi in orchids, isolated living *Melanotus* mycelia from orchid tissue. The isolated dikaryotic cultures subsequently fruited, and the resultant basidiomata were identified as *Melanotus*.

E. Species Concepts in Fungi

1. Morphological species concept (MSC)

The type method, a cornerstone of nomenclatural stability and a founding principle of the International Code of Botanical Nomenclature (ICBN), determines the use of binomial names. Traditionally, gross morphology and microscopic characteristics of basidiomata have been used to infer genetic relationships within and

between members of the Agaricales with subsequent applications of a name (i.e., binomials) to rank taxa (Fries, 1821, 1838, Persoon, 1801; Karsten, 1876; Saccardo, 1887; Singer, 1951, 1962, 1975, 1986).

These traditional methods of classification ("alpha taxonomy") are based on intuitive or subjective decisions concerning overall phenotypic similarity of the organisms under study. Grouping and ranking organisms based on an estimate of a defined measure of similarity (phenetics) is a preferable method of analysis in alpha taxonomy, as it permits reanalysis of the measure by another taxonomist using a second set of observations (Dunn and Everitt, 1982). Phenetics can be summed up as overall relationship based on similarity, whether it is morphological, physiological, or genetic. (Wiley, 1981, Heijerman, 1996)

The MSC has its roots in Aristotelian logic (Brummit, 1997) and the classical taxonomic work by Linnaeus (1754), and is at the heart of contemporaneous classification schematics. Taxa are nested hierarchically and do not overlap. The use of an MSC to predict evolutionary relationships between organisms has been criticised by many authors (De Queiroz and Good, 1997; De Queiroz and Gauthier; Welzen, 1997). Sokal and Sneath (1963) provide a lengthy discussion on why phenetic techniques are effective in the classification of organisms, as do Heijemann (1996) and Brummit (1997).

2. Biological species concept (BSC)

According to Mayr (1942, 1969, 1970) and Dobzhansky (1970) biological species may be defined as reproductively isolated groups that actually or potentially

interbreed. In the saprobic Basidiomycotina intercompatibility is based on a genetic system that regulates the ability of organisms to successfully dikaryotize.

Blakeslee (1904) was the first to determine the extent of compatibility in the common bread mold *Rhizopus*, and designated the terms homothallic (self-fertile), and heterothallic (not self-fertile i.e., requiring outcrossing to complete sexual cycle) to describe sexual behavior (Blakeslee, 1906, 1920). Later, Raper (1966) determined the extent of mating compatibility in other groups of fungi. Incompatibility in fungi can be defined as "the restriction of mating competence controlled by genes other than those determining sexual differentiation" (Esser and Blaich, 1994).

Perkins (1994) stressed the importance of designating between interfertility and intersterile groups of fungi. Other authors (Donoghue, 1985, Mishler, 1985, Mishler and Donoghue, 1982; Mishler, 1994) have drawn similar conclusions regarding the use of a BSC to define species. It must be emphasized that the basic tenets of the biological species concept as conceived by Mayr (1942, 1969, 1970) and Dobzhansky (1970) are based on sexually reproducing animals, and not fungi (i.e, specifically the saprotrophic Agaricales). Both incompatibility and intersterility genes can affect the extent of inbreeding vs. outbreeding in a population of Agarics and the degree of gene flow between two populations of fungi, respectively (Chase and Ullrich, 1990). This is indicative that the ability to produce sexually viable offspring included in the the biological species concept (Mayr 1942, 1969, 1970; Dobzhansky, 1970) may be not neccesarily be reflective of what is occurring at the genetic level in saprophytic (Agaricales) fungi. Morphologically similar, intersterile populations of fungi

reproductively isolated from each other are often assumed to to represent early stages of sympatric speciation (Burnett, 1983, Petersen and Hughes, 1999). In this light partial compatibility within an intersterility group may also be reflective of genetic divergence, promoting outbreeding over time (Burnett, 1975, Petersen and Hughes, 1999).

In the Agaricales it has been determined that two primary incompatibility systems operate (see Raper, 1966, for an historical account). They have been described as: 1) multiallelic genes at a single locus A, (A1, A2, etc.) defining a unifactorial (bipolar) mating system; or 2) multiallelic genes at two unlinked loci A and B defining a bifactorial (tetrapolar) mating system. The explanations for the functioning of the mating type loci are based primarily on two tetrapolar taxa, *Schizophyllum commune* and *Coprinus cinereus*.

Petersen (1995a, b) provided a detailed discussion of mating systems in other fungi, elaborating on putative evolutionary mechanisms operating within and between fungi based solely on mating system data. In some basidiomycetes, particular attention must be given to amphithallic mating systems and the possible role amphithallism may play in regulating gene exchange between fungi (i.e., promoting inbreeding as a means of self-replication). Such a system of inbreeding could possibly enhance the proceess of colonization and fruiting on otherwise diminishing substrata. Putative amphithallism (see below) may occur in some collections of *Melanotus*. If amphithallism does truly occur in *Melanotus*, it could be advantageous as *Melanotus* can be found fruiting on ephemeral substrates.

In a typical life cycle of a saprophytic agaric two monokaryotic mycelia come into contact, and if compatible, undergo plasmogamy with subsequent dikaryotization (Petersen and Hughes, 1999). In most agarics this stage in the development of the heterokaryotic mycelium is marked by the presence of clamp connections (see Table 2) at transverse septa, and is typically indicative of conjugate nuclear divisions.

Table 2. List of Terminology.

Clamp connections- a distinct hyphal outgrowth formed as a result of successful plasmogamy of two separate monokaryotic hyphae. Process results in a secondarily dikaryotic mycelium that undergoes conjugate nuclear divisions.
Interlamellar hyphae- in *Melanotus*, a micromorphological distinct zone from the trama proper and pileal trama; typically cellular or interwoven. Located in between the gills.
parietal - pigments in or on the hyphal cell wall. epiparietal granular- hyphae encrusted wuth granules or warts of pigments. epiparietal stippled- hyphae irregularly banded with pigment.
Sympleisomorphies- groups defined using shared primitive characters.
Monophyletic- a group that is descended from a common ancestor.
Paraphyletic- including some, but not all, descendents of a single, common ancestor.
Vegetative compatibility- the ability of two separate mycelia to anastamose and undergo succsessful plasmogamy without accompanying cell lysis.
Amphithallism- a basidiospore that may contain more than one nucleus and thus carry all the genes necessary for a heterothallic life cycle within the single spore.

Boidin (1986) provided a summary and discussion of the use of incompatibility studies in fungal systematics. Boidin (1986) suggested that morphologically similar taxa may be tested: 1) to infer if reproductive isolation is taking place; 2) to indicate degree of genetic relatedness of geographically isolated species; 3) to determine the

range of morphological variation operating between and within intersterility groups; and 4) to determine the biogeographical range in a biological species.

Several studies have reported *in vitro* intercompatibility within taxa collected across wide geographic ranges (Petersen and Bermudes, 1992a,b; Petersen and Hughes, 1993; Petersen and McCleneghen, 1995; Petersen and Wu, 1991). It was determined that fungal populations were contaxic based on no inherent barriers to gene flow. The work of Gordon and Petersen (1982) has demonstrated that geographically isolated populations of the same morpho-taxon could be partially incompatible. Petersen (1995a) outlined some observations of the former phenomena using the dissertation work of Scott Gordon (1994). Sime (Sime and Petersen, 1999) has found worldwide disjunct collections of *Melanotus* to be virtually intercompatible. Additional data on morphology confirmed that the collections were phenotypically indistinguishable (see below).

Several authors (Donoghue, 1985; Mishler, 1985; Mishler and Donoghue, 1982) have challenged the biological species concept as conceived by Mayr (1942, 1963) and Dobzhansky (1937). They argued that the concept did not include monophyletic groups based on sympliesomorphies. However, some have cautioned against blindly accepting the validity of monophyletic groupings (Margulis, 1991).

Other workers (Masters, et al. 1987) have regarded the biological species concept as including a dichotomy, citing recognition and isolation theorems as conceptually and empirically distinct ideas within the BSC. While their ideas stemmed mostly from classical studies on speciation involving mammals (Darwin, etc.), they offered

suggestions on how Patersons's (1978, 1980, 1981) ideas on the Recognition Species Concept (RSC) carry "greater explanatory and predictive power" than the "deficient" BSC. However, many concepts of the RSC have been addressed in work on vegetative compatibility in fungi (Anagnostakis, 1984; Leslie, 1993). Furthermore, they felt (Masters, et al. 1987) that "an additional prediction coming directly from the RSC is "Allopatric speciation is the most prevalent, if not the only mode of speciation." Literature on mating studies in saprotrophic agaric members suggests exactly the opposite, (Boidin, 1986; Duncan, 1972; Duncan and MacDonald, 1967, Petersen and Hughes, 1999): partial interincompatibilty among sympatric taxa may be indicative of ongoing speciation.

3. Molecular species concept (MOSC)

Molecular techniques used for assessing genetic variation in fungi encompass a variety of methods, and have been reviewed by Bruns et al (1991) and Kohn (1992). Each technique has certain limitations, and can provide resolution only at certain levels (Kohn, 1992). DNA techniques allow the use of genetic markers to establish the identity of individuals, in addition to taxonomic and phylogenetic relationships between individuals. DNA-DNA hybridiziation and sequencing of ribosomal DNA were among the first molecular techniques to be used in the study of fungi (Werman, et al, 1990). Since that time, the use of restriction enzymes, Southern hybridization, gel electrophoresis, and restriction fragment length polymorphism (RFLP) have also become commonplace in the study of fungal genetic and evolutionary relationships.

Even more recent is the application of polymerase chain reaction (PCR) in the study of fungi (Mullis et al., 1986, 1987). This technique allows exponential amplification of certain DNA sequences by DNA synthesis, and a rapid means to prepare microgram quantities of DNA for subsequent analysis. Since its inception, PCR has been used in the majority of taxonomic studies for the last 10 years (Lammers, 1999). DNA amplification fingerprinting (DAF) is similar to Random Amplified Polymorphic DNA (RAPD) in that they both produce a series of electrophoretic bands that can be scored as either present /absent. The bands are the result of DNA polymerase-mediated amplification of random, specific sites along the DNA strand. Typically, presence or absence of a band is indicative of an allelic difference. However, DAF produces more bands (amplicon products) as the reaction mixture used in DAF contains higher primer to template ratios than RAPD and subsequently produces up to four times as many bands. Trigiano and Caetano-Annollés (1998) provided a summary and review of DAF techniques and their relative applicability.

Molecular "species" in DAF are defined in a similar manner as they are in "enzymatic" species. Typically electrophoretic phenotypes are scored as characters and entered into a variety of statistical software algorithms. Samples are compared based upon overall similarity to each other via the biochemical markers generated in the specific molecular technique being used, which is dependent upon the level of resolution the investigator is pursuing.

F. Purpose of Study

Traditional taxonomic studies in the Agaricales have been conducted solely within a morphotaxonomic framework (= MSC). Several authors have advocated the use of a pluralistic species concept (Donoghue, 1985; Mishler, 1985; Vilgalys, 1991) which incorporates the use of several data sets- i.e., molecular techniques, interbreeding, morphology, ecology.

Consequently, in order to determine if certain ecological, macro- and micromorphological characters are taxonomically informative, several *Melanotus* basidiomata and cultures (Appendix A) have been procured for study and subjected to MSC, BSC, and MOSC analyses for defining taxa within the genus. It was already determined that three morphological species (*sensu* Horak, 1977; Watling and Gregory, 1987, Redhead and Kroeger, 1984) belonged to a single biological species i.e., *M. horizontalis* (Sime and Petersen, 1999), and that substratum appeared to play no role in defining morphological and biological species in that complex.

For this study, the following hypotheses were proposed: 1) general substratum characteristics (*i.e.*, monocot vs. dicot, angio- vs. gymnosperm) are not taxonomically informative for delineating taxa within *Melanotus*; 2) certain micromorphological characters (i.e., basidiospore, basidium ranges) that possess significant overlap are not useful in the delineation of taxa within *Melanotus*; 3) other pertinent micromorphological characters (*i.e*, cheilo-, pleuro-, caulocystidia ranges, etc.) correlate with intersterility groups; 4) molecular data may be useful for delineating

otherwise morphologically ambiguous taxa; and 5) intercompatible groups of collections within *Melanotus* will possess similar electrophoretic profiles.

II. MATERIALS AND METHODS

A. Study Materials

Collections of fresh basidiomata were made in North America, South America, Europe, and AustralAsia. Locations in North America included the United States: Washington, California, Tennessee, and North Carolina. Canadian locations included the provinces of British Columbia and Ontario. Collections were also made in Argentina, Scotland, Australia (Tasmania), New Zealand, and New Caledonia. Specimens, with or without cultures, were borrowed from other researchers and institutions from Canada (Dr. Scott Redhead, DAOM), United States: Washington (Dr. Joe Ammirati, WTU), California (Dr. David Largent, HSU), New York Botanical Garden (Dr. Roy Halling, NYBG); and Southeast Asia: Malaysia (Dr. Tom Lassoe, C) Type and additional specimens were borrowed as appropriate from the following herbaria: LPS, K, FH, BAFC, F, L, E, PC.

All basidiomata collected fresh during the course of this study are deposited at the University of Tennessee mycological herbarium (TENN). Cultures (monokaryons and dikaryons) are stored in CULTENN mycological culture collection. All collections utilized in this study for morphological, compatibility, and DNA fingerprinting are summarized in Appendix A.

B. Morphology

1. Macro- and micromorphological techniques

Fresh basidioma collected in the field were removed from their substratum and placed in plastic tackleboxes for transportation to the laboratory. In the lab each

collection was assigned a unique TENN field number. Color standards by Kornerup and Wanscher (1967) were used for macromorphological notes on colors and are cited alphanumericaly below. Colors are identified by two numbers and letter (e. g., 5B 3). The first number corresponds to the page on which the plate is found, the letter indicates the column for the color, and the second number identifies the row(s) for the specific color (s).

A description of macromorphological features, ecological parameters, and locale data were also recorded for each collection. When possible, specimens were photographed with Ektachrome ASA 200 color slide film on a standard gray card backdrop. Basidiomata were dried on a warm-air drier, boxed and assigned a TENN mycological herbarium database number. All herbarium acronyms are based on the 8th edition of the Index Herbariorum (1990: New York Botanical Garden Press). Taxonomic keys by Horak (1977) and Watling and Gregory (1987) were used to initially identify specimens.

An Olympus B-7 microscope was used for all micromorphological analyses. Descriptive terminologies are based on those by Largent (1986), Largent and Baroni, (1988), Largent et. al., (1977) Singer (1986) Bas et. al., (1988), and Parmasto and Parmasto (1987).

Notes were compiled from dried specimens rehydrated with 95% ethanol for 20 minutes. Specimens were then rinsed in deionized (di) water and subsequently soaked in 10% NH_4OH. Sections of specimens were prepared by placing the specimen between pith (*Sambucus* sp.) pre-soaked in 95% ethanol, and cut with a double-edged

razor blade. Sections up to 10 μm thick were deposited in di water in the inverted lid of a petri plate. Thin, clean sections were identified under an Olympus stereo microscope at 25X magnification.

The following sections were utilized to elucidate micromorphological characters: 1) tangential sections: entire basidiomata were used to examine pellicle structure from the disc area to the pileus margin in serial sections, also subpellis, pileus trama, lamellar trama, hymenium and subhymenium, lamprocystidia, caulocystidia, and stipe hyphal arrangement; 2) squash mounts of lamellae in cases where hymenial and cystidial characteristics could not be discerned; and 3) scalp sections to examine pellicle structure and pileocystidia.

Basidospores were measured from deposits on pileus surfaces primarily, and lamellae secondarily (in cases where the collection was miniscule or fragmented). A total of 20 basidiospores (n = 20) from each collection was measured for the following characteristics: 1) length x width range (l x w); 2) mean length (L_x) and mean width (W_x); 3) spore quotient in profile (Q = length/width); 4) volume ((V=4π/3)*a*b*c); 5) breadth range (B_R); 6) mean breadth (B_x); 7) polar width range (P_{WR}); 8) polar width mean (P_{BX}); 9) polar breadth range (P_{BR}); 10) polar breadth mean (P_{BX}); 11) apical germ pore centric or eccentric; and 12) wall thickness in μm.

A total of 20 measurements were used for all other micromorphological structures. A list off all macro- and micromorphological characters coded in this study can be found in Appendix B.

2. Morphological character data analysis

All morphological coded characters were entered into DELTA (Appendix B). An MS-DOS character program was written that included 168 macro- and micromorphological features of the 45 basidiomata utilized in this study (Appendix B). Characters consisted in three states; two-state, quantitative, and multistate. A gap-coding method (Almeida and Bisby, 1984) was utilized to transform quantitative characters into discrete unordered characters.

Characters were then used to construct a distance matrix in the DELTA program using the general similarity coefficient of Gower (1971). Resultant distance matrices were then converted into a format suitable for analysis in the program Numerical Taxonomy and Multivariate Analysis System (Rolf, 1992; NTSYS-pc, v. 1.8, Exeter Software, NY). The clustering algorithm Unweighted Pair Group Method using Arithmetic Averages (UPGMA) was then used to analyze the distance matrices. This analysis produced a dendrogram for each distance matrix. Cophenetic correlation (Sokal and Michener, 1958) in MXCOMP program of NTSYS was used to measure "goodness of fit" between the original distance matrix and subsequent UPGMA dendrograms.

3. Type specimen studies

Notes and descriptions of type materials are provided in section C., Type Studies. Macromorphological descriptions were either 1) derived from the original protologue; or 2) derived from dried basidiomata when possible. Protocols are listed above. A list of all examined type collections may be found in Appendix A.

C. Compatibility Experiments

1. Monokaryon isolation and storage

Monokaryotic mycelium was derived from fresh collections in one of two methods: 1) a basidiospore deposit was collected from a basidioma on sterilized aluminum foil, assigned an TENN field book number, and stored at 5° C. Spores of *Melanotus* stored in this manner were found to be viable up to five years. At a later time an inoculating needle was used to scrape spores off the aluminum foil. Spores were deposited into a 155 x 45 mm presterilized Kimax test tube (Fisher Scientific, Atlanta, GA) with 10 ml of sterile di water. The tube was gently vortexed for 2-3 seconds to disperse the spores. A sterilized pipette was used to withdraw a 1 ml aliquot of spore suspension, which was transferred to another 10 ml of sterile water. Serial dilutions were made in 0.1, 0.01, 0.001, and 0.0001 concentrations of basidiospores. Each tube containing the serial dilutions was vortexed gently for 2-3 seconds, and 1 ml was spread on a 65 x 15 mm standard Petri plate (Falcon, Fisher Scientific, Atlanta, GA), containing 2% malt agar (see Appendix C), and water was allowed to evaporate. Spores were examined every 3-8 hours for germlings. Once germination occurred, germlings (single-basidiospore isolates: SBIs) were harvested with a dentist pick #10-explorer probe, and transferred to a fresh MEA Petri plate.

Once sufficient growth had occurred, Petri plate colonies were assayed for presence or absence of clamp connections under 200X magnification on an Olympus B-7 microscope. Randomly chosen 5 mm blocks from were placed on a microslide in 10% NH_4OH and absence of clamp connections confirmed under 1000X-2250X. If

clamps were absent, an additional 5 mm block of excised mycelium was examined for nuclear number under epifluorescence microscopy (methods decribed below). Fifteen mm discs were excised from monokaryotic colonies and transferred to 1.7 ml glass vials containing 1.0 ml di H_20 (Fisher Scientific, Atlanta, GA) and stored at 15° C.

2) An entire basidioma was affixed to the lid of a 65 x 15 mm standard MEA Petri plate with Vaseline, the lid replaced, and parafilmed. The Petri plate was then placed at a ≅70° angle until visual evidence of spore deposition was evident. Once a spore deposit was evident, the basidioma was retrieved from Vaseline and dried for microscopic analysis. Spores were examined every 3-8 hours until germlings were evident. Germlings were subsequently harvested and stored as previously mentioned. Once it was determined that a colony was monokaryotic, the colony was then used for self-cross and intercollection analysis.

2. Epifluorescence microscopy

Nuclear condition of all isolates was confirmed under epifluorescense. A 5 mm block of mycelium was placed on a microslide in DAPI (4', 6-Diamidino-2-phenylindole dihydrochloride, a cationic fluorescent dye that specifically binds to adenine-thymine-rich DNA), where nuclear number was ascertained. A single nucleus per unit cell of hyphae was interpreted as monokaryotic, whereas two nuclei was deemed dikaryotic.

3. Intraspecific collection crosses

All collections made within a geographically defined area were paired against each other using four SBIs derived from each collection (n = 4) to determine the extent of intersterility groups operating between the collections (Appendix H, part C).

If all pairings were found to be intercompatible, one to several collections were chosen as exemplars for self-cross analysis and used to represent that popoulation in DNA fingerprinting analysis and the intercollection pairing experiments. Any collection(s) that were interINcompatible were subjected to a self-cross (when SBIs were available) and subsequently added to the DNA fingerprinting analysis.

4. Intracollection self-crosses

Self-crosses of selected collections representing different geographic locales were made by pairing 10-12 SBIs in all possible combinations. All collections utilized for self-cross analysis appear in Appendix I.

Pairings were performed by placing a 5 mm block of mycelial innoculum 10 mm apart on MEA Petri plates. Isolates were allowed to grow at room temperature for three weeks. At three weeks a contact zone had significantly developed, and results were scored according to methods by Petersen and Methven (1994). Compatible matings were scored by the presence of clamp connections in the contact zone, incompatible pairings by their absence. Nuclei were routinely stained with DAPI to ascertain karyotic state when clamp connection formation was ambiguous. Four tester strains were then randomly assigned. Tester strains were then used whenever possible in subsequent intercollection pairings.

5. Intercollection compatibility analysis

If a collection used for intercollection experiments did not receive a self-cross, four SBIs were selected at random for intercollection crosses. Otherwise exemplar collection(s) tester strains derived from above techniques were paired against all other collection exemplar SBIs to determine the intersterility groups operating between and within the study taxa (n = 4-16). Pairings were performed as described above. After two-three weeks, 5 mm blocks from the contact zone and obverse sides of the Petri plate were squashed and examined on a microslide in 10% NH_4OH for completely fused clamp connections under 1000X-2250X magnification.

Once the presence of fused clamps was verified, an additional 5 mm block of mycelium was squashed with DAPI to confirm nuclear condition under epifluorescence at 1000-2250X. A subculture of the contact zone was then placed on a new MEA Petri plate. Once the subculture was determined to bear fused clamps the secondary mycelial colony was considered dikaryotic and the two exemplars were judged intercompatible (Petersen, 1995).

D. DNA Amplification Fingerprinting Analysis

1. Culture preparation

Forty-four collections of *Melanotus* taxa representing several geographic locales were used for DNA fingerprinting analysis (Table A-1). Dikaryotic isolates were grown in malt broth media (hereafter referred to as MB; See Appendix C). Approximately 25 ml aliquots of MB were placed into 150 ml Erlenmeyer flasks and innoculated with mycelia. Cultures for DNA isolation were grown for two weeks at

18° C with 70 μmol·sec^{-1}·m^{-2} light provided by cool white fluorescent tubes. Mycelium was decanted from liquid cultures onto Whatman no. 1 filter paper using a vacuum, deposited into a sterile pouch, and immediately frozen at –70° C.

2. DNA extraction

DNA extraction was conducted using the following methods. See Appendix D for all recipes and stock solutions. Approximately 250-400 mg of frozen mycelium was placed in a pre-chilled mortar and ground to a fine powder with liquid nitrogen. Next, an addition of 0.5 g of polyvinylpolypyrrolidone (PVPP) and a second aliquot of liquid nitrogen was added, and the mycelium re-ground. Once the mycelium was in a fine, granular power 1000 μl of cell lysis solution (PureGene, Hercules, California) was added, the sample re-ground, and allowed to thaw. The resultant slurry was alloted into 1.5 ml microcentrifuge tube(s), and incubated at 65° C for one hour.

After incubation samples were cooled to room temperature and centrifuged for 10 min. at 14,000 RPM. Next approximately 600 μl of protein precipitation solution (PureGene, Hercules, California) was added to 600 μl of prep solution, vortexed 10 sec., and centrifuged for 10 min. at 14,000 RPM. The aqueous supernatant was then transferred to another sterile 1.5 ml microcentrifuge tube to which 100% isopropanol was added in a ratio of 1:1. Tubes were inverted and then placed at –20° C for 60 minutes. After freezing, tubes were centrifuged at 14,000 RPM for 10 min..

The resultant supernatant was carefully poured off and discarded, subsequently the tubes and pellets were air-dried for 15 min.. The pellet was then resuspended in 70% ethanol, inverted several times to mix, and centrifuged at 14,000 RPM for 3 min..

After centrifugation the supernatant was carefully poured off, and discarded. The tubes were then air dried for 5-15 min., and the pellet resuspended in 50 µl of double-distilled (ddi) nano-pure water and stored for 24 hrs at 2° C. After 24 hrs. the samples were vortexed, centrifuged at 14,000 RPM for 2 min., and transferred to a new, sterile 1.0 ml microcentrifuge tube and stored at 2° C.

Genomic DNA was resuspended in 45 µl of ddi and quantified by fluorescent enhancement of the dye H33258 using a TKO 100 fluorometer (Hoefer, San Francisco, CA) DNA extraction consistently yielded between 15 and 100 ng per approximately 250-400 mg of mycelium. DNA stocks were then diluted to yield concentrations of 5 ng/µl in ddi for PCR, and amplified according to the methods of Caetano-Annollés et. al. (1991).

3. PCR conditions

Reaction (PCR) mixtures consisted of 5 ng of template DNA, 200 µM of dNTP, 100 mM $MgCl_2$, and 3 µM of primer. Ten primers were used to amplify the extracted DNA (see Appendix E for primer sequences). DNA was amplified in a thermocycler (Easy Cycler Twin Block System, Ericomp Inc., San Diego, CA) for 35 cycles (at 5.5 min each cycle) of 10 seconds each at 30° C and 96° C.

4. Gel electrophoresis

Amplified products were diluted 1:1 with ddi and the samples prepared for electrophoresis by mixing 3 µl of diluted PCR products with 3 µl of loading buffer. See appendix F for all recipes and stock solutions. Hand-cast 10% polyacrylamide gels were cast on a Protean II electrophoresis cells (Bio-Rad, Hercules, CA). Gels

were assembled to the Protean II electrophoresis rig, and pre-run for 15 min.. All wells were subsequently cleaned with running buffer via a tuberculin syringe with a 1.5 inch long, 25 gauge needle. Products were separated on 10% polyacrylamide gels backed on GelBond (FMC Bioproducts, Rockland, ME) using a constant voltage of 180 V. Electrophoresis was terminated when the tracking dye was about 1.75 cm from the bottom of the gel. DNA was subsequently visualized using a fast and sensitive staining protocol that can detect picogram quantities of DNA (Bassam et al., 1991)

Once electrophoresis was completed, gels were removed from the mini-protean II rig, and placed in 7.5% acetic acid (see Appendix F for recipes and stock solutions) for 10 min. on a rotary shaker at 60 rpm. Gels were then rinsed with ddi three times each for 2 min. on a rotary shaker at 60rpm. After rinsing off the base, the gels were soaked in silver stain for approximately 20 min. on a rotary shaker for 60 rpm. Upon completion of the silver stain soak gels were rinsed with ddi for approximately 20 sec., and then placed in a developer. Developing occurred on a rotary shaker at 60 rpm and continued until bands were dark, usually 5-8 min.. Once the gels were developed they were fixed in 4 C acetic acid for 5 min. at 60 rpm on a rotary shaker, then soaked in anticracking solution for 5 min. on a rotary shaker at 60 rpm. Once anticracked, gels were hung overnight to dry and subsequently stored in a non-polyvinyl-chloride emitting photo album.

5. Data analysis

Products from PCR amplification (bands) from single primers representing 44 isolates of *Melanotus* species were examined on a light box and those of 700 bp or less scored as present (1) or absent (0). In cases were product was not available or presence/absence of a band was in question, the locus was assigned a (9) to indicate missing or uncertain data. An n x t table was set up and subjected to SIMQUAL (Similarity for Qualitative Data) in NTSYS to calculate a similarity matrix based on Dice's (1945) similarity coefficient. Next a dendrogram was assembled using SAHN (Sequential, agglomerative, hierarchical, and nested) clustering methods using Unweighted Pair Group Cluster Analysis Using Arithmetic Means (UPGMA).

E. Combined Analyses

In contemporaneous literature there is no set standard on how to evaluate data from differing character suites (Huelsenbeck et al., 1996; Mishler, 1994; Swofford, 1990). Therefore data from the morphological and molecular character suites will be combined and analyzed separately. Data from the mating studies will be correlated with the phenetic trees to determine if intersterility groups are affiliated with biochemical markers generated from the molecular character suite.

III. RESULTS

A. Morphology

A total of 45 collections labeled as either *Melanotus* or *Crepidotus* were initially identified using the keys by Horak (1977), Singer (1984) and Watling and Gregory (1987). All collections are listed in Appendix A. According to these keys, basidioma sorted into the following morphotaxa: 1) one of *M. bambusinus*; 2) two of *M. hepatochrous*; 3) two of *M. horizontalis*; 4) two of *M. proteus*; 5) three of *M. defraudatus*; 6) three of *M. alpiniae*; 7) seven of *M. patagonicus*; 8) eight of *M. textilis*; and 9) seventeen of *M. eccentricus*. Out of 45 identified collections 44 had corresponding dikaryotic cultures and were used for DNA fingerprinting analysis. Out of the 44 dikaryons 30 had accompanying SBIs and were used in intercompatibility experiments.

Characters used for all morphological analyses are listed in Appendix B. The morphological UPGMA phenogram of 45 collections is furnished in Figure 1. All examined type collections with the exception of DAOM 188219 (*M. textilis* Redhead & Kroeger) were in poor condition. Despite careful preparation it was impossible to recover a full suite of morphological characters; therefore type specimen analysis includes 18 micromorphological features of basidiospores. Specific character suites that provided greater reliability were selected for diagnosis in the process of distance generation. These characters were selected based on Watling and Gregory's (1987) treatment of *Melanotus* and also from personal observation. Utilized characters that provided greater reliability were: (21-23) pileus color; (123) pileal trama hyphal

inflation; (135-138) interlamellar characteristics; (139-143) subhymenium characteristics, and (42-43) basal tomentum characteristics. Final UPGMA phenograms were constructed emphasizing these characters suites.

Phenetic analyses were conducted on all 45 collections. Two additional phenetic analyses were conducted on: 1) 44 collections (subset of 45) that had accompanying dikaryotic isolates used for DAF; 2) 30 collections (subset of 45) that had more than two viable accompanying SBIs used for intercompatibility studies; and 3) 45 collections and 13 type collections. Results from all analyses were consistent, and are are shown in the following figures.

The UPGMA dendrogram is shown in Fig. 1. Based on the UPGMA morphological phenogram three groups are recognized within the 45 collections of *Melanotus* used in this study. Results of this analysis were inconsistent with the morphotaxonomic summary of Horak (1977) and Watling and Gregory (1987). Both Horak (1977) and Watling and Gregory (1987) placed emphasis on the following characters (found within the DELTA character program file) to segregate taxa within *Melanotus*: 1) pileus shape and color; 2) lamellar attachment; 3) stipe insertion; 4) suprapellicle arrangement; 5) spore shape in face view; 6) spore l x w ranges; 7) cheilocystidium shape; 8) cheilocystidium l x w ranges; and 9) substratum characteristics. The results of the present study indicated that significant overlap existed among these characters, and they appeared to be of limited use in delineating taxa within *Melanotus*. As a consequence, names assigned to the 45 collections of *Melanotus* based on Horak's (1977) and Watling and Gregory's (1987)

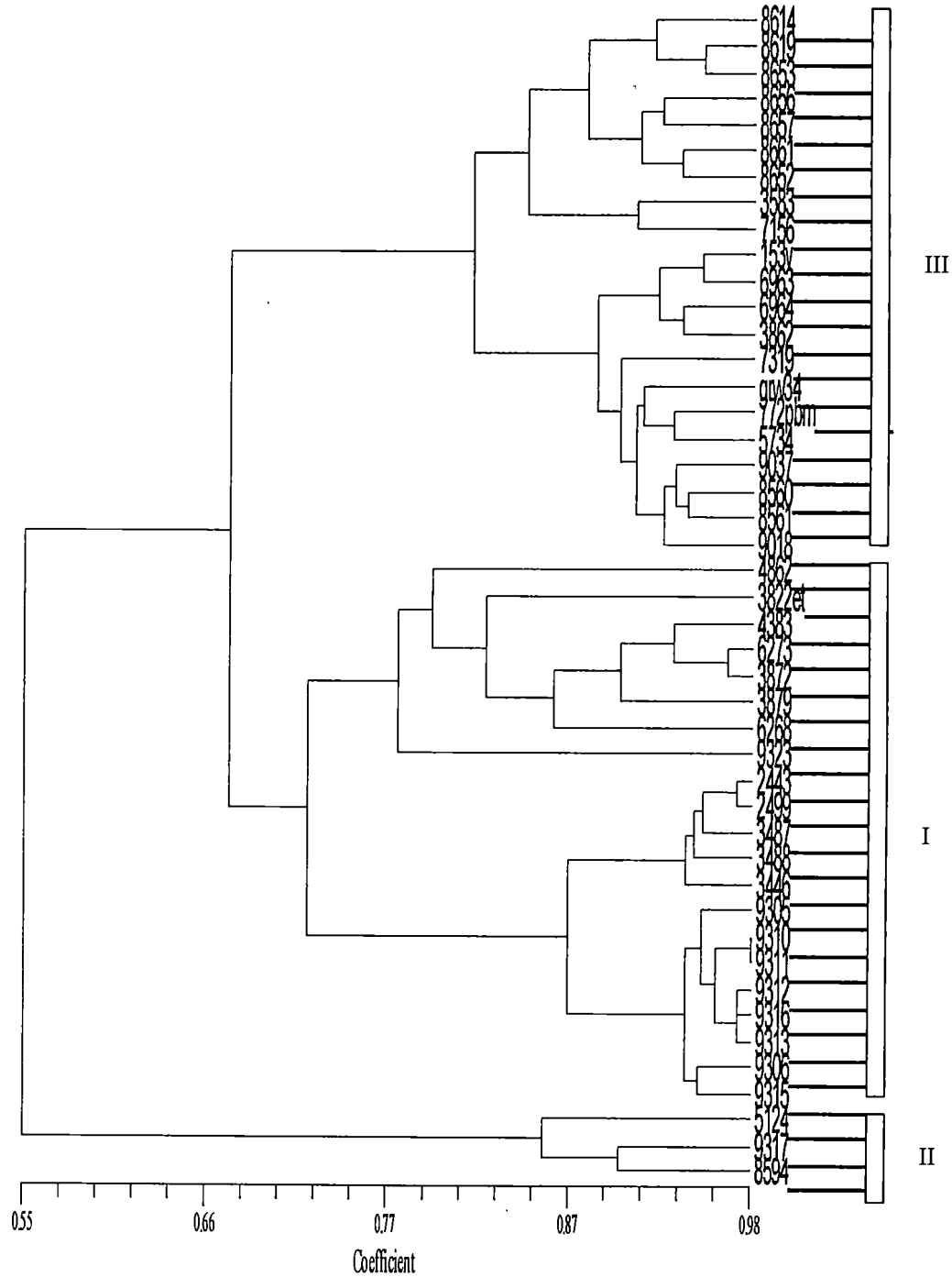


Figure 1. All-Collection (Without Type Specimens) Morphological DELTA UPGMA phenogram of 45 *Melanotus* collections utilized for macro- and micromorphological comparisons. Phenogram was constructed utilizing NTSYS-PC v. 1.04 and is based upon 168 macro- and micromorphological characters. Cophenetic correlation (r) = 0.96. Scale at bottom represents a numerical measure of similarity.

morphotaxonomic keys could not be accepted; and did not correlate with morphological data suites generated within this study.

Since all collections examined within each group (I-III, respectively) were found to conform to the same range of measurements and architecture, the following inclusive descriptions can be offered for each group:

1. Group I: **Pileus** (-1)2–15(-20) mm diam.; pileus shape in youth convex, in adult basidiomata unchanged, at first conchate in profile, later remaining conchate, surface in youth dull, with age remaining dull, texture smooth; disc tomentose; in between disc and margin tomentose; margin in youth inrolled, with age remaining inrolled; margin surface tomentose; margin in youth entire, remaining entire, with a non-striate appearance; pileal disc deep yellow to pale-yellow (4A, 2–8) or grey-brown (6F, 3-8), between disc and margin deep yellow to pale yellow (4A, 2-8) or grey-brown (6D-F, 3). **Lamellae** adnate, thin, in tangential section equal; lamellae close or crowded; margin at first entire, with age remaining even; lamellae in youth concolorous with pileus, with age also concolorous with pileus; face concolorous with pileus. **Stipe** in youth a pad of tissue; stipe insertion in youth (primordial stage) central, or eccentric; stipe in age (pileus exhibiting full lateral extension) becoming eccentric; stipe in profile equal; stipe base swollen or equal, concolorous with pileus; stipe surface glabrous; stipe in length 2–5 mm; basal tomentum present, appressed to substratum, collar-like ring of felty mycelium.

Basidiospores in profile amygdaliform, or amygdaliform with acute apex; spores in frontal view obovoid; *l x w range* = (6-)6.5–7 (-8) x (4-)5–5.5 μm; L_x = 6.85 μm;

W_x = 5.01 µm; *spore Q in profile exactly* 1.36 µm; V = 98.95 um^3; *Breadth range* (B_R)= (5.2-)5.5–6 µm; *mean breadth* (B_x) = 5.51 µm; *Polar width range* (P_{WR}) = (4-)5–5.5(-6) µm; *Polar width mean* (P_{WX}) = 5.45 µm; *Polar breadth range* (P_{BR}) = (4-)5–5.5(-6) µm; *Polar breadth mean* (P_{BX}) = 5.17 µm; apical germ pore distinct, and centric, wall thickness less than or equal to 0.5 µm. **Basidia** originating in the subhymenium; basidia equal to clavate; L_x = 15.4 µm; W_x = 6.13 µm; l x w range = (14-)15–16(-18) x 5–6(-7) µm; sterigmata 4. **Cheilocystidia** abundant, cheilocystidia originating in the hymenium; mucronate, cylindrical or sphaeropedunculate to ventricose-rostrate; apex glandular capitate; L_x = 19.12 µm; W_x = 4.37 µm; l x w range = 18–21 x 4–5(-6) µm; wall pigments absent. **Pleurocystidia** abundant, or embedded with an emergent neck; pleurocystidia originating in the hymenium; clavate or ventricose-rostrate to clavate or cylindrical; apex glandular capitate; L_x = 20.06 µm; W_x = 4.66 µm; l x w range = (15-)18–21(-24) x 4–5(-6) µm. **Suprapellis** a lattice; hyphal diam. range = (2-)3–5 µm; hyphal diam. mean 4 µm; wall thickness 0.6 to 1.0 µm; clamp connections present; hyphal external pigments epiparietal stippled; light-brown. Hyphal elements that extrude from pellicle hyphae filiform to remaining unchanged; hyphal diam. range = 2–3 µm; mean diam. = 2.5 µm; wall thickness less than or equal to 0.5 µm; hyphal pigments absent. **Mediopellis** absent. **Subpellis** absent. **Mucus** depth at disc 5–30 µm. **Pileus trama** interwoven or interwoven with swollen elements; hyphal wall thickness 0.6 - 1.0 µm; hyphal diam. mean = 7 µm; hyphal diam. range 5–8(-9) µm; hyphal inflation present; clamp connections present;

wall pigments absent; **Pileocystidia** when present scattered; pileocystidia pyriform or clavate to sphaeropedunculate; L_x = 18.2 µm; W_x = 4.3 µm; l x w range = (12-)15–20(-22) µm; apex acute or dichotomous to forked more than two times; wall pigments absent.

Lamellar trama subparallel to interwoven; hyphal wall thickness less than or equal to 0.5 µm; hyphal diam. range = 5–8(-9) µm; hyphal diam. mean = 6.45 µm; wall pigmentation absent. **Interlamellar** organization cellular; hyphal diam. range = (8-)10–15(-17) µm; hyphal diam mean. = 12.6 µm. **Subhymenium** parenchymatous; hyphal wall pigments absent; cell diam. range = (4–)5–6(–7) µm; cell diam. mean = 5.6 µm. **Stipe** pellicle hyphae parallel; stipe hyphal medullary zone indistinct from pellis; stipe hyphal wall thickness 0.6 - 1.0 µm; stipe pellis average range diam. 2.5–3 µm; stipe hyphal wall pigments epiparietal stippled; light-brown. **Caulocystidia** absent. **Substratum**: hardwood and monocot debris, dead or living.

Commentary: Basidiomata of all examined collections within Group I are diagnosed as follows: 1) pileus color deep yellow or pale yellow (4A, 2-8) to grey-brown (6F, 3-8); 2) pileal trama hyphal inflation present, hyphal mean diam. = 9 µm; 3) interlamellar hyphal organization cellular, hyphal diam. mean = 12.6 µm; 4) subhymenium parenchymatous, hyphal diam. mean = 5.6 µm; and 5) basal tomentum appressed to substratum, collar-like ring of felty mycelium.

2. Group II: **Pileus** 1.5–3.5 mm diam.; shape in youth convex, in adult basidiomata later flabelliform, at first conchate in profile, later becoming ovoid,

surface in youth dull, with age becoming dry, texture felty; disc glabrous; between disc and margin glabrous; margin in youth incurved, with age becoming wavy; margin surface matted-tomentose; in youth entire, becoming undulated, with a non-striate appeance; pileal disc off-white (1A1), in-between disc and margin off white (1A1); margin off white (1A1). **Lamellae** adnate, thin, in tangential section clavate; crowded; lamellar margin at first smooth, with age becoming fimbriate; lamellae in youth concolorous with pileus, with age also concolorous with pileus; lamellar face concolorous with pileus. **Stipe** in youth absent. **Substratum**: on grass, living or dead.

Basidiospores in profile amygdaliform; in frontal view ovoid; *l x w range* = 6–6.5 (-7) μm; L_x = 6.0 μm; W_x = 3.72 μm; V = 46.48 μm^3; *Breadth range* (B_R)= 3.8–4 μm; *mean breadth* (B_x) = 3.98 μm; *Polar width range* (P_{WR}) = (3-) 3.5–4 (-4.2) μm; *Polar width mean* (P_{WX}) = 3.82 μm; *Polar breadth range* (P_{BR}) = 3–4 μm; *Polar breadth mean* (P_{BX}) = 3.8 μm; apical germ pore distinct and centric, wall thickness less than or equal to 0.5 μm. **Basidia** originating in the subhymenium; equal to clavate; L_x = 14.3 μm; W_x = 4.9 μm; l x w range = (13-) 14–15 μm; sterigmata 2–4. **Cheilocystidia** clustered in tufts; cheilocystidia originating in the hymenium; fusoid, to urtriform; glandular capitate; L_x = 16.1 μm; W_x = 4.9 μm; l x w range = 15–16 (-18) μm; wall pigments absent. **Pleurocystidia** absent. **Suprapellis** a lattice; hyphal diam. range = 2–4 μm; hyphal diam. mean 2.91 μm; wall thickness less than or equal to 0.5 μm; clamp connections present; hyphal external pigments epiparietal granular; yellow. Hyphal elements that extrude from pellicle hyphae irregularly branched, to filiform; hyphal diam. range = 2–3 μm; mean diam. = 2 μm; wall thickness less than or equal to

0.5 μm; hyphal wall external pigments absent. **Mediopellis** absent. **Subpellis** absent. **Mucus** depth at disc 70 μm. **Pileus trama** interwoven; hyphal wall thickness less than or equal to 0.5 μm; hyphal diam. mean = 4 μm; hyphal inflation absent; clamp connections present; wall pigments absent. **Pileocystidia** absent. **Lamellar** trama interwoven, to subparallel; wall thickness less than or equal to 0.5 um; hyphal diamter range = 3–4(-5) μm; hyphal diam. mean = 3.6 μm; wall pigmentation absent. **Interlamellar** organization similiar to pileal trama. **Subhymenium** indistinct from trama proper. **Caulocystidia** absent.

Commentary: Basidiomata of all examined collections within Group II are diagnosed as follows: 1) pileus color off white (1A 1); 2) pileal trama hyphal inflation absent; 3) interlamellal organization similiar to pileal trama; 4) subhymenium indistinct from lamellar trama; and 5) basal tomentum absent.

3. Group III: **Pileus** 1.5–9 mm diam.; shape in youth convex, in adult basidiomata later convex or later applanate, at first ovoid in profile or conchate in profile, later becoming dimidiate, surface in youth dull, with age remaining dull, texture smooth; pileus disc matted tomentose; between disc and margin tomentose to matted-tomentose; pileus margin in youth plane, with age remaining inrolled; pileus margin surface tomentose; margin in youth entire, becoming undulated or remaining entire, with a plicate-striate appearance; pileal disc orange white (5A-2) or golden-yellow (5B, 7) to red-brown (8D-E, 4-8), in-between disc and margin greyish-orange (5B, 3-6), brown-yellow to brown-orange (5C, 8–3), yellow-brown to dark blond (5D,

4-8) to dark brown (&E-F, 4-8); margin brown-yellow to brown-orange (5C, 8–3), yellow-brown to dark blond (5D, 4-8) to red-brown (8D-E, 4-8). **Lamellae** adnate, thin, in tangential section clavate; crowded; lamellar margin at first entire, with age becoming fimbriate; lamellae in youth concolorous with pileus, with age also concolorous with pileus; face concolorous with pileus. **Stipe** in youth a pad of tissue or a fully formed stipe; stipe in age remaining unchanged; stipe insertion in youth (primordial stage) central or eccentric; stipe in age (pileus exhibiting full lateral extension) becoming eccentric; stipe in profile equal; stipe base swollen or equal; concolorous with pileus; in length 2-12 mm; surface glabrous; basal tomentum circular, cottony, subiculum-like, with cottony, aerial mycelium. **Substratum**: On wood (*Almus* sp., *Betula* sp. *Nothofagus* sp. *Picea* sp. and *Sequoia* sp) and monocot (*Chusquea culeo*).

Basidiospores in profile elliptic, or amygdaliform; in frontal view elliptic, or ovoid; *l x w range* = (6.4-)7.2–8(-8.8) µm; L_x = 7.55 µm; W_x = 4.87 µm; *spore Q in profile exactly* 1.55 µm; V = 97.36 µm^3; *Breadth range* (B_R)= (4.5-)5–5.5 µm; *mean breadth* (B_x) = 5.06 µm; *Polar width range* (P_{WR}) = 5–5.5(-6) µm; *Polar width mean* (P_{WX}) = 5.25 µm; *Polar breadth range* (P_{BR}) = (4.5-)4.8–5 µm; *Polar breadth mean* (P_{BX}) = 4.94 µm; apical germ pore distinct, and centric, wall thickness 0.6 to 1.0 µm. **Basidia** originating in the subhymenium; clavate, constricted sub-apically; L_x = 19.26 µm; W_x = 5.61 µm; l x w range = (15-)17–20(-22) x 5–6(-7) µm; sterigmata 2–4. **Cheilocystidia** abundant; cheilocystidia originating in the hymenium; ventricose-rostrate or cylindrical to capitulate; glandular capitate; L_x = 19.45 µm; W_x = 4.95 µm;

l x w range = (17-)18–22(-23) x (4-)5–6(-7) μm; wall pigments absent. **Pleurocystidia** scattered but frequent, or embedded with an emergent neck; pleurocystidia originating in the hymenium; venricose-rostrate or cylindrical, to capitulate; L_x = 20.4 μm; W_x = 4.5 μm; l x w range = (18-)20–22(-23) x 4–5 μm; apex glandular capitate; wall pigments absent. **Suprapellis** a lattice; hyphal diam. range = (4-)4–6(-7.5) μm; hyphal diam. mean 4.4 μm; wall thickness greater than or equal to 1.1 μm; clamp connections present; hyphal externál pigments epiparietal granular; golden-brown. Hyphal elements that extrude from pellicle hyphae filiform, to irregularly branched; hyphal diam. range = 2–3; mean diam. = 2.2 μm; wall thickness less than or equal to 0.5 μm; hyphal wall external pigments absent. **Mediopellis** absent. **Subpellis** absent. **Mucus** depth at disc 10–20 μm. **Pileus trama** interwoven; hyphal wall thickness 0.6 to 1.0 μm; hyphal diam. mean = 5.5 μm; hyphal diam. range (4-)5–7(-8) μm; hyphal inflation absent; clamp connections present; wall pigments absent. **Pileocystidia** absent. **Lamellar** trama interwoven to subparallel; wall thickness less than or equal to 0.5 μm; hyphal diam. range = (5-)6–7(-8) μm; hyphal diam. mean = 6.27 μm; wall pigmentation absent. **Interlamellar** organization similiar to pileus trama. **Subhymenium** parenchymatous; hyphal wall pigments absent; cell diam. range = (4–)5–9(–11) μm; cell diam. mean = 6.38 μm. Caulocystidia absent.

Commentary: Basidiomata of all examined collections within Group III are diagnosed as follows: 1) pileus color orange-white (5A 2) to red-brown (8D-E, 4-8); 2) pileal trama hyphal inflation absent; 3) interlamellal organization similiar to pileal

trama; 4) subhymenium parenchymatous, hyphal diam. mean = 6.38; and 5) basal tomentum circular, cottony, subiculum-like, with cottony, aerial mycelium.

B. Type Studies

Although three comprehensive morphotaxonomic species could be identified, several species epithets qualified as candidates for synonymy under *M. alpiniae* and *M. horizontalis*. Type specimens were examined and commentary on these types is furnished here in order to provide a basis for such synonymy and to preclude further examination of already extremely sparse material. A Morphological UPGMA analysis of types specimens and Groups I-III follows (Fig. 2). Descriptions of type specimens are listed alphabetically by epithet.

Agaricus alpiniae Berkeley, 1856. Hook. J. Bot. 8: 133.

≡ *Melanotus alpiniae* (Berkeley) Pilát, 1950.Trans. Br. mycol. Soc. 33: 216.

≡ *Crepidotus alpiniae* (Berkeley) Saccardo, 1887.Syll. Fung. 5: 886.

BRAZIL: PANURÉ, Jan. 1853, *R. Spruce*, on *Alpiniae aromatica*, Spruce 114, (K(M) 57577) HOLOTYPE of *C. alpiniae*. [!]

Morphological Analysis: *Basidiospores in profile* elliptic, or broadly elliptic; *in frontal view* ovoid; *l x w range* = (6-)6.5–7(-8) x (4-)4.2–4.5(-5) µm; L_x = 6.2 µm; W_x = 4.0 µm; *spore Q in profile exactly* 1.52 µm; V = 1.52 µm^3; *Breadth range* (B_R) = (4-)4.2–4.5(-5) µm; *mean breadth* (B_x) = 4.29 µm; *Polar width range* (P_{WR}) = (4.2-)4.5–5 µm; *mean* (P_{WX}) = 4.73 µm; *breadth range* (P_{BR}) = (4-)4.2–5 µm; *breadth mean* (P_{BX})

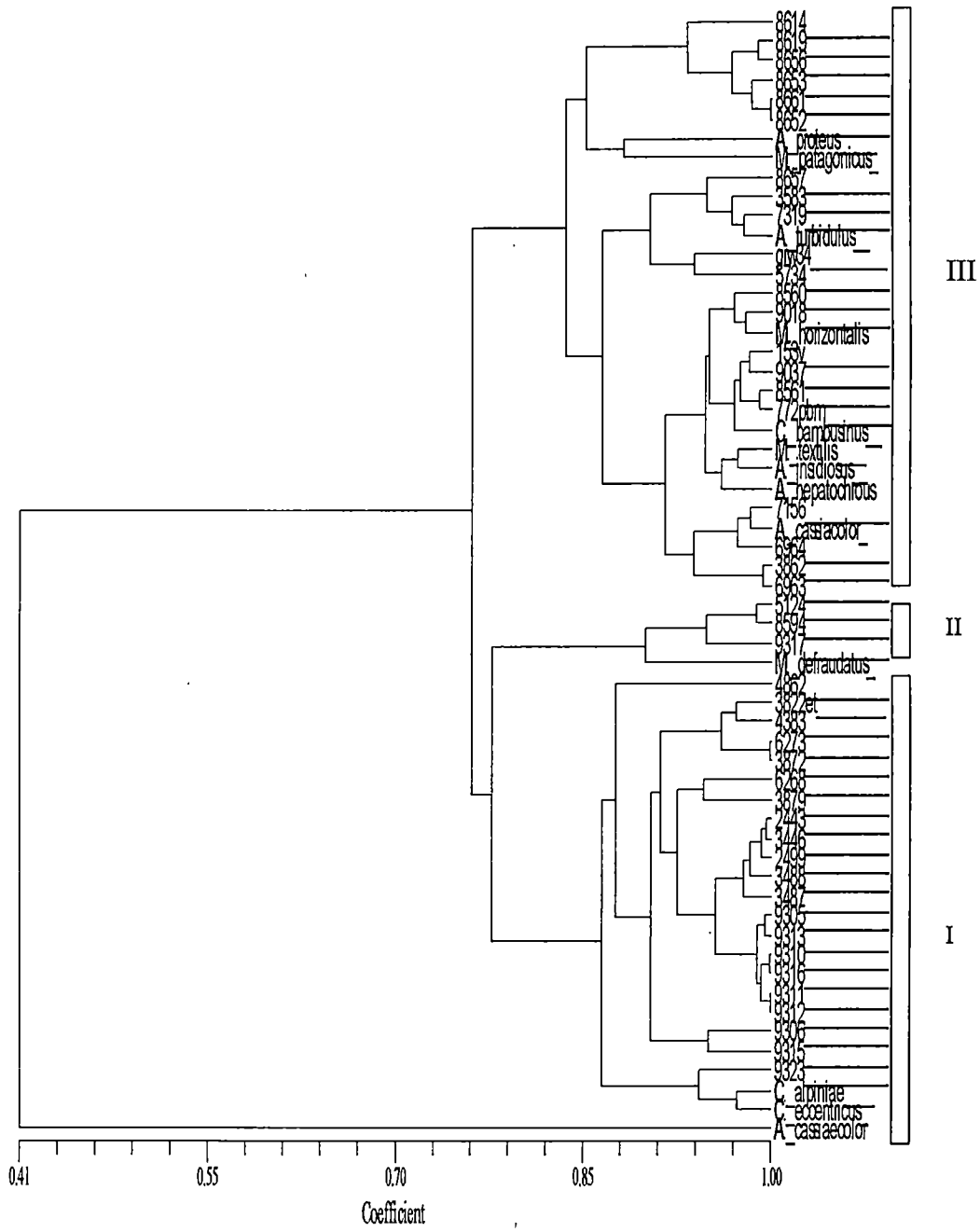


Figure 2. All-Collection (With Type Specimens) Morphological DELTA UPGMA phenogram of type specimens and 45 *Melanotus* collections based on 18 basidiospore characteristics. Cophenetic correlation (r) = 0.98. Scale at bottom represents a numerical measure of similarity.

= 4.4 µm; *apical germ pore* distinct; *and* centric; *wall thickness* less than or equal to 0.5 µm.

Commentary: The type specimen was found to be compressed to such a degree that it was impossible to fully rehydrate the specimen, consequently only spore microcharacters were obtainable. Horak (1977) also listed the type as being in poor condition, and did not provide spore data. Pilát (1950) lists 8.5 x 5.5 µm, slightly longer than 7 µm reported above. Similarity analysis clusters this taxon basal to the type collection of *M. eccentricus*.

Crepidotus bambusinus Patouillard J. Bot. Paris, 5(18): 309. 1891.

≡ *M. bambusinus* (Patouillard) Patouillard, 1900. Essai tax.: 175.

VIETNAM: Ke So, Tonkin, on putrid Bambusae, H. Bon, 28.VIII.1890, 4464/HN, HOLOTYPE of *M. bambusinus*.[!]

Morphological analysis: The following characters were observable: 1) *Basidiospores in profile* elliptic or amygdaliform; *in frontal view* elliptic or ovoid; *l x w range* = 6–6.5 x (3.8-)4–4.5(-5) µm; L_x = 6.11µm; W_x = 4.0µm; *spore Q in profile exactly* 1.5 µm; V = 56.08 µm; *Breadth range* (B_R)= 4–4.5(-5) µm; *mean breadth* (B_x) = 4.32 µm; *Polar width range* (P_{WR}) = 4–4.5(-5) µm; *mean* (P_{WX}) = 4.32 µm; *breadth range* (P_{BR}) = 4–4.5 µm; *breadth mean* (P_{BX}) = 4.14 µm; *apical germ pore* distinct; *and* centric; *wall thickness* up to 0.5 µm; 2) Basidia originating in the subhymenium, cylindrical to clavate, 12-13 x 4-5 µm; sterigmata appear 2-4 µm; 3) suprapellis a

lattice; hyphae 2-3 μm diam, wall thickness less than or equal to 0.5 μm; hyphal external pigments epiparietal stippled, light-brown.

Commentary: *Melanotus* (*Crepidotus*) *bambusinus* was first based on a specimen on rotten bamboo from Tonkin, Vietnam. The type consists of one basidiomata broken into two sections. Despite meticulous preparation, it was impossible to revive the specimen properly for analysis. All tissues were glassy and adherent. Overlap in spore characteristics were observable between *M. bambusinus* and the following types: *M. textilis, M. hepatochrous, M. horizontalis*, and *M. insidiosus*. Pilát (1950) reported a spore range of 6-7 x 4.5-5 μm on the type of *M. bambusinus*, which correlates with these observations. Similarity analysis places the type collection of *M. bambusinus* within Group III: *M. horizontalis*, due to overlapping spore length and width ranges exhibited between the collections. *Melanotus bambusinus* is not treated here as part of Group III since 1) only spore characters were extractable from the type collection; and 2) no collections were available for use that derived from the topotype locale of *M. bambusinus*, so concordance between the two epithets could not be ascertained.

Agaricus cassiaecolor Berkeley, 1848.in Hook., J. Bot. 7: 574.

≡ *Melanotus cassiaecolor* (Berkeley) Singer, 1950. Sydowia 15: 70.

≡ *Crepidotus cassiaecolor* (Berkeley) Saccardo, 1887. Syll. Fung. 5:882.

AUSTRALIA: Tasmania, on wood, W. Archer, K (M) 57579 as *M. cassiacolor* LECTOTYPE of *M. cassiaecolor*. [!]

AUSTRALIA: Tasmania, on wood, Archer, K (M) 60101 as *M. cassiaecolor*

PARATYPE of *M. cassiaecolor*. [!]

Morphological Analysis: I have determined the spore characteristics for K(M) 60101 as follows: Basidiospores in profile broadly elliptic; in frontal view cylindric, or ovoid; *l x w range* = (8.2-)9–10(-11.5) x (6-)6.2–7.2(-8) µm; L_x = 9.51 µm; W_x = 7.05 µm; *spore Q in profile exactly* 1.34 µm; V = 270.87 µm; *Breadth range* (B_R)= (7.2-)7–8(-9) µm; *mean breadth* (B_x) = 7.72 µm; *Polar width range* (P_{WR}) = (6.8-)7–7.3(-7.8) µm; *Polar width mean* (P_{WX}) = 7.5 µm; *Polar breadth range* (P_{BR}) = (7-)7.2–7.5(-7.8) µm; *Polar breadth mean* (P_{BX}) = 7.1 µm; apical germ pore distinct or indistinct, and centric, wall thickness 0.6 to 1.0 µm.

The spore characteristics for K(M) 57579 are : Basidiospores in profile elliptic, or ovoid, or amygdaliform; in frontal view elliptic, or oblong, or ovoid; *l x w range* = (6-)6.5–7 x (4-)4.5–4.8(-5) µm; L_x = 6.78 µm; W_x = 4.3 µm; *spore Q in profile exactly* 1.57 µm; V = 75.37 µm; *Breadth range* (B_R)= 4.5–5 µm; *mean breadth* (B_x) = 4.94 µm; *Polar width range* (P_{WR}) = (4-)4.5–4.8(-5.5)µm; *Polar width mean* (P_{WX}) = 5.2 µm; *Polar breadth range* (P_{BR}) = (4.8-)5–6(-6.2) µm; *Polar breadth mean* (P_{BX}) = 4.76 µm; apical germ pore distinct, and centric, wall thickness 0.6 to 1.0 µm.

Commentary: Pilát (1950), in a revisionary study of some types of *Crepidotus*, lists a spore range of 7.5-8.5 x 5-5.6 µm, and cites material examined as: "Typus in herbario Kewensi ex herbario M. C. Cooke 1885. Duo carposomata. Tasmania, leg. W. Archer." In a transferral of *C. cassiaecolor* to *Melanotus* Singer (1952) cites the type material examined as "Archer, on indetermined wood in Tasmania" and furnished

a spore size range of 8.2-10.3 x 6-6.2 µm. In a later study, Singer (1969) provided a spore size range of 8-11 x 5.7-7.7 µm, and cited "Tasmania: Leg. Archer (K), typus" as part of his material examined. Horak (1977) did not provide any spore measurements for the type of *M. cassiaecolor*, treating *M. cassiaecolor* as a facultative synonym under *M. hepatochrous*. Horak (1977) cited "Tasmania, Archer (holotype of *Agaricus cassiaecolor* Berk., K)" as material examined. No collection number was provided.

Part of a herbarium loan of *M. cassiaecolor* from Kew were two specimens, designated as TYPE on their respective labels bearing the following numbers: K(M) 60101, and K(M) 57579. The former specimen was labeled as *M. cassiaecolor*, the latter as orthographic variant *M. **cassaecolor***. Reference to Berkeley's (1860) protologue showed that Berkeley had made no reference to a collection number. In fact, the protologue reads "Hab. On dead bark, Archer. A larger form occurs on charred wood, approaching in size to *A. hepatochrous*, Berk., and there is also a smaller form on decorticated wood." The reported spore range by Singer (1969) and Pilát (1950) and ADS appears to coincide with collection K(M) 60101. However, labels included with K(M) 60101 read: *M. cassiaecolor*, type, coll. Archer: and a small label: "Ag (*Crepidotus*) Tasmania, Archer." There is a small card with a single piece of wood affixed to the card. The wood includes a fragment of a carpophore. My analysis finds that the pileipellis appears gelatinized and pigmented as reported by Singer (1969); but spore shape appears broadly elliptical to elliptical in profile, dacryoid to globose in face view, not "scarcely lentiform, ellipsoid in lateral view

often slightly phaseoliform" as reported by Singer (1969). There is no indication of M. C. Cooke on the labels which accompany specimen K(M)60101, as cited by Pilát (1959) in his study of the type.

The label with specimen K(M)57579 reads: "*M. cassiacolor*, Coll. Archer," and Type is checked. A small label inside package reads " *Crepidotus cassiaecolor* Berk., Type material, Tasmania, Archer." The card to which the specimen is affixed reads "*Agaricus* (*Crepidotus*) *cassiacolor* Berk. Tasmania, Archer." A purple stamp reads "Herb MTCLL M. C. Cooke 1885". This then, agrees with Pilát's (1950) type analysis. However, my spore measurements for this collection (K(M)57579) are 6-7 x 4-4.5 µm, which do not agree with Singer (1969) nor Pilát's (1950) reported spore range of the type of *Melanotus* (*Crepidotus*) *cassiaecolor*. Because Berkeley does not provide a collection number, it is difficult to say on which collection (K(M)57579/K(M)60101) he based his original description of *A. cassiaecolor*. Since both collections cite Tasmania, Archer and only collection K(M) 57579 has "type material" on the inside packet, based on rules 9.4-9.5 of the Code of Botanical Nomenclature, it is assumed that K(M) 57579 and K(M) 60101 can be considered syntypes, with K(M) 57579 designated here as lectotype to serve as the nomenclatural type of *M. casssiaecolor* Berkeley. Collection number K(M) 60101 is not similar to any other collection used this study based upon the cluster analysis. Collection number K(M) 57579 is most similar to the type of *M. proteus* based on the UPGMA analysis.

Melanotus defraudatus Horak, Desjardin, and Petersen, 1990. Mycologia 82:4 493-495.

USA: North Carolina, Macon Co, Blue Valley, RHP, 30.VIII.89, Field no. 2230, (TENN 48119). [!]

Morphological Analysis: Basidiospores in profile amygdaliform; in frontal view ovoid; *l x w range* = 5.6–6.4 x 3.2–4 µm; L_x = 6.12 µm; W_x = 3.8 µm; *spore Q in profile exactly* 1.61 µm; V = 48.68 µm^3; *Breadth range* (B_R)= 3.5–4 µm; *mean breadth* (B_x) = 4 µm; *Polar width range* (P_{WR}) = 3.5–4 µm; *mean* (P_{WX}) = 3.86 µm; *breadth range* (P_{BR}) = 3–3.5 µm; *breadth mean* (P_{BX}) = 3.13 µm; apical germ pore distinct, and centric, wall thickness less than or equal to 0.5 µm.

Commentary: *Melanotus defraudatus* appears to represent a distinct morphotaxonomic species. This is the first report of *M. defraudatus* occuring outside of North Carolina. Based on the UPGMA analysis, the type collection of *M. defraudatus* is identical to the three collections of *M. defraudatus* used in this study. See Horak et al (1990) for a complete description of the type collection.

Crepidotus eccentricus Murrill N. Am. Fl. 10:155. 1917.

≡ *Melanotus eccentricus* (Murrill) Singer. Lilloa 13:87:1947.

JAMAICA: Kingston, East of Hope Gardens, on dead herbaceous stems, 12.VII.1908, WA Murrill, WA Murrill 21, HOLOTYPE of *M. eccentricus*. [!]

Morphological Analysis: *Basidiospores in profile* elliptic, or broadly elliptic; *in frontal view* ovoid; *l x w range* = 6–6.5 x 4–4.5(-4.8) µm; L_x = 6.04 µm; W_x = 4.09

µm; *spore Q in profile exactly* 1.47 µm; V = 58.17 µm^3; *Breadth range* (B_R)= 4–4.5(-5.5) µm; *mean breadth* (B_X) = 4.5 µm; *Polar width range* (P_{WR}) = 4.5–4.8(-5) µm; *mean* (P_{WX}) = 4.64 µm; *breadth range* (P_{BR}) = 4–4.5(-5) µm; *breadth mean* (P_{BX}) = 4.37 µm; *apical germ pore* distinct; *and* centric; *wall thickness* less than or equal to 0.5 µm.

Commentary: Horak (1977) regarded the characters of a well-developed, centric to eccentric cylindrical stipe and slender spores (3-4 µm) as separating *M. eccentricus* from *M. alpiniae*. I have found the spore range for the type specimen of *M. eccentricus* to be 6-6.5 x 4-4.5(-4) µm, while Murrill (1917) listed spore dimensions as 5-6 x 4-5 µm, and Hesler and Smith (1965) listed spores as 5.3-6 x 4-5µm. Unfortunately the type collection consists of a few fragments of basidiomata, and only spore characteristics were discernable. In this study, all *Melanotus* on which a stipe is present retain the identical characteristic central to eccentric, cylindrical stipe, this character cannot be considered valid for the segregation of *M. eccentricus* from *M. alpiniae*. In addition, spore width was not found to be a valid character based on the observations by Hesler and Smith (1965) and Murrill (1917); see there for a complete description of the holotype of *M. eccentricus*. Based on the morphological UPGMA phenogram the type specimen of *M. eccentricus* is most similar to type collection of *C. alpiniae*.

Agaricus hepatochrous Berkeley, 1848. Hook., J. Bot 7: 574.

≡ *Melanotus hepatochrous* (Berkeley) Singer, 1951. Sydowia 5: 472.

≡ *Crepidotus hepatochrous* (Berkeley) Saccardo, 1887. Syll. Fung. 5: 877.

AUSTRALIA: Tasmania, on wood, Herb. Berk no. 756, [as Gunn, No. 1787, May, 1845, Berk., Lond. J. Bot 7:574], K (M) 48937, HOLOTYPE of *M. hepatochrous*. [!]

Morphological Analysis: Basidiospores in profile elliptic, or ovoid, or amygdaliform; in frontal view elliptic, or oblong, or ovoid; *l x w range* = (5.2-)6–6.5(-7) x (3-)3.2–4.2(-4.5) µm; L_x = 5.99 µm; W_x = 3.93 µm; *spore Q in profile exactly* 1.52 µm; V = 54.32 µm^3; *Breadth range* (B_R)= 4–4.5(-5) µm; *mean breadth* (B_x) = 4.41 µm; *Polar width range* (P_{WR}) = (4-)4.2–4.5(-4.8) µm; *Polar width mean* (P_{WX}) = 4.53 µm; *Polar breadth range* (P_{BR}) = 4–4.5 µm; *Polar breadth mean* (P_{BX}) = 4.12 µm; apical germ pore distinct, and centric, wall thickness 0.6 to 1.0 µm.

Commentary: In the protologue to *A.* (*Crepidotus*) *hepatochrous* Berk. (1848) Berkeley stated his specimen as : "Gunn, No. 1787. Hab. On bark, May, 1845". The label on *M. hepatochrous* packet at Kew states: "K(M) 48937. Australia: Tasmania. Coll. Herb Berk. No. 756. Type." The label inside the packet reads "Type collection. *Agaricus* (*Crepidotus*) *hepatochrous* B. , Herb. Berk. No. 756. Tasmania, Gunn." Basidiomata are loosly bundled up in tissue-paper, not affixed to any card.
Horak (1977) listed "Gunn, 756" as holotype examined and reported a basidiospore range of 5.5-7.5 x 3.5-5 µm for *M. hepatochrous*. No further documentation indicates that Berkeley had Gunn's specimen 1787, but labeled it as Berk. 756, nor does Horak

(1977) elaborate. Pilát (1950) cited "Typus in herbario Kewensi: Tasmania, Berkeley, No. 756."and gave a spore range of 6-6.7 (-7) x 5.3-5.6 µm. Singer (1951a) stated that the type specimen "comes from Tasmania" and did not provide a spore range. The type collection of *M. hepatochrous* clusters with the type collection of *M. textilis* and *M. insidiosus* based upon the UPGMA analysis. *Melanotus hepatochrous* appears to be morphologically identical to *M. insidiosus*. Both collections may have been been part of a single gathering that was split into two by Berkeley, since both collections share similar collections numbers (see commentary below on *M. insidiosus).*

Agaricus insidiosus Berkeley, 1848. Hook., J. Bot. 7: 574.

≡ *Melanotus insidiosus* (Berkeley) Pegler, 1964. Austr. J. Bot. 13: 336.

≡ *Crepidotus insidiosus* (Berkeley) Saccardo, 1887. Syll. Fung. 5: 882.

AUSTRALIA: Tasmania, Penquite, on bark, May, 1845, with no. 1787, K (M) 57578 HOLOTYPE of *M. insidiosus*. [!]

Morphologica Analysis: Basidiospores in profile elliptic, oblong or ovoid; in frontal view elliptic, oblong, or ovoid; L_x = 6.15; W_x = 4.01; *spore Q in profile exactly* 1.53; V = 54.98 um^3; *Breadth range* (B_R)= 4–4.8; *mean breadth* (B_x) = 4.26 um; *Polar width range* (P_{WR}) = (4-)4.2–4.8(-5); *Polar width mean* (P_{WX}) = 4.66 um; *Polar breadth range* (P_{BR}) = 4–4.8; *Polar breadth mean* (P_{BX}) = 4.18 um; apical germ pore distinct, and centric, wall thickness 0.6 to 1.0 um.

Commentary: In the protologue (Berkeley, 1848) of *A.* (*Crepidotus*) *insidiosus* Berkeley the sole specimen is listed as "With Number 1787. May, 1845. Hab.

Penquite. On bark." Horak (1977) cited only the following "Penguite [*sic*], May 1845 (holotype of *A. insidiosus* Berk, K)" as specimen studied. Pilát (1950) reported "Typus in herbario Kewensi: Penquite, Tasmania," and gave a basidiospore range of 7-8.5 x 4-4.5 µm for *M. insidiosus*. Singer (1952) provided a spore range of 6.02-7 (8.2) x 4-5.5 µm, and states "The type comes from Tasmania".

The specimen packet (label K(M) 57578, type, Penquite) of *M. insidiosus* reveals: 1) a card with small linear piece of wood with a dimidiate *Melanotus* on it; 2) a smaller fragment of wood (broken off former?) with a basidioma affixed; and 3) label reading "Penquite, No. 1787" written in very fine, thin handwriting.

Based on the protologues by Berkeley for *A. insidiosus* and *A. hepatochrous*, identical collection dates and locales are noted. Both collections have identical collection numbers, except the type collection of *M. hepatochrous* (K(M) 48937) has "Gunn." If both collections derive from a single gathering, the type specimen of *M. hepatochrous* K(M) 48937 and the type specimen from *M. insidiosus* could represent a split collection. Without further documentation, however, it is difficult to say whether or not there is a nomenclatorial difference between "Gunn 1787' and 'With no. 1787'. The type collection of *M. insidiosus* is most similar to the type collection *of M. textilis*, while the type specimen of *M. hepatochrous* clusters basal to both *M. hepatochrous* and *M. insidiosus*.

Melanotus patagonicus Singer, 1969. Beih. Nova Hedw. 29: 258.

ARGENTINA: Prov. Nuequen, Puerto Manzano, *Ad lignum putrescente*, R. Singer, Singer no. M 3060, (BAFC 23963), 17-III-1963, HOLOTYPE of *M. patagonicus*.[!]

Morphological Analysis: Basidiospores in profile elliptic; in frontal view ovoid; *l x w range* = (6.5-)7–7.5(-8) x (4.2-)4.5–5(-5.5) µm; L_x = 7.0 µm;; W_x = 4.8 µm;; *spore Q in profile exactly* 1.46 µm; V = 95.25 µm^3; *Breadth range* (B_R)= 5.2–5.5(-6) µm;; *mean breadth* (B_x) = 5.33 µm;; *Polar width range* (P_{WR}) = 5.2–5.5(-6) µm;; *Polar width mean* (P_{WX}) = 5.6 µm;; *Polar breadth range* (P_{BR}) = (4.8-)5–5.5 µm;; *Polar breadth mean* (P_{BX}) = 5 µm;; apical germ pore distinct, and centric, wall thickness 0.6 to 1.0 µm

Commentary: Singer (1969) listed a basidiospore range of (6) 6.3-7.8 x 5-5.5 (4.5-5) µm; and Horak (1977) 6-7 (7.5) x 4-5 µm for the type collection of *M. patagonicus*. Horak (1977) stated this taxon should be placed directly between *Psilocybe* and *Melanotus* due to the presence of a predominantly centrally inserted stipe. Based on the UPGMA analysis *M. patagonicus* clusters with the type collection of *M. proteus*.

The gross morphology of the type basidiome of *M. patagonicus* differs significantly from members of Group III, *M. horizontalis* and all other collections utilized in this study. All carpophores studied exhibited a predominantly central stipe, the base of which resembles a pseudo-volva, to which small particles of substratum cling. Without any further contaxic collections, it is difficult to predict the relevance of these macromorphological features.

Agaricus turbidulus Berkeley apud Saccardo, 1887. Syll. Fung. 5: 889

≡*Crepidotus turbidulus* (Berkeley) Saccardo, 1891. Syll Fung. 9: 117.

AUSTRALIA: Tasmania, on wood, K (M) 57580, HOLOTYPE of *M. turbidulus*. [!]

Morphological Analysis: Basidiospores in profile elliptic, or ovoid, or amygdaliform; in frontal view elliptic, or oblong, or ovoid; *l x w range* = (6-)6.5–7(-8) x (3.5-)4–5; L_x = 6.87; W_x = 4.15; *spore Q in profile exactly* 1.65; V = 72.51 um^3; *Breadth range* (B_R)= (4-)4–5(-5.5); *mean breadth* (B_x) = 4.86 um; *Polar width range* (P_{WR}) = (4.5-)5–5.5(-6); *Polar width mean* (P_{WX}) = 5.04 um; *Polar breadth range* (P_{BR}) = (4-)4.5–5; *Polar breadth mean* (P_{BX}) = 4.59 um; apical germ pore distinct, and centric, wall thickness 0.6 to 1.0 um.

Commentary: The type of *A. turbidulus* clusters within Group III, M. *horizontalis*, and is most similar to the collections no. 7319 (USA, CA) and 3583 (Australia, Tasmania) based on the UPGMA analysis of type specimens. Pilát (1950) reports a slightly larger basidiospore range of 7.5-8.3 x 5.6 µm than reported here, while Saccardo (1891) listed a spore range of 6-7µm.

Agaricus proteus Kalchbrenner. apud Thümen, 1876. Flora 59: 424.

≡ *Melanotus proteus* (Kalchbrenner. apud Thümen) Singer, 1946. Lloydia 9: 130.

SOUTH AFRICA: in ligno humido, fabrefacto, clathrato, vitifero, hortensi prope Somerset-East, Promont: bonae spei. Kalchbrenner, Jan. 1876, Leg. P. MacOwan;

Exsic. no. 503, *M. proteus*, LECTOTYPE of *M. proteus* (FH) [!], ISOTYPE of *M. proteus* (DAOM) [!].

Morphological Analysis: *Basidiospores in profile* elliptic, or ovoid, or amygdaliform; *in frontal view* elliptic, or oblong, or ovoid; *l x w range* = (6-)6.5–7 x (4-)4.5–5 µm; L_x = 6.78 µm; W_x = 4.64 µm; *spore Q in profile exactly* 1.46 µm; V = 79.84 µm^3; *Breadth range* (B_R)= 5–5.2 µm; *mean breadth* (B_x) = 4.85 µm; *Polar width range* (P_{WR}) = (4-)5–5.5 µm; *mean* (P_{WX}) = 5.37 µm; *breadth range* (P_{BR}) = (4.5-)5–5.5(-6) µm; *breadth mean* (P_{BX}) = 5 µm; *apical germ pore* distinct; *and* centric; *wall thickness* 0.6 to 1.0 µm.

Commentary: Two collections were borrowed from FH and DAOM both labeled isotype of *M. proteus*. I have determined both collections to be morphologically identical, therefore the isotype collection of *M. proteus* from FH is designated as lectotype. Sime and Petersen (1999) have reported on the circumscription of *M. proteus* by various authors. The results of the cluster analysis place the type collection of *M. proteus* as most similar to the type collection *of M. patagonicus*.

Agaricus horizontalis Bulliard, 1787-88. Herbier de la France. Tome 7, fasc. 78-84, pl. 324.

UNITED KINGDOM: England, Essex, Monks Wood, Epping Forest, on Beech stump, 10.X.82, Martin Gregory, Orton 5316 (E 00037827) EPITYPE of *M. horizontalis*. [!]

Morphological Analysis: *Basidiospores in profile* elliptic, or ovoid, or amygdaliform; *in frontal view* elliptic, or oblong, or ovoid; *l x w range* = (5.6-)6.4–7.2(-8) x (3.5-)4–4.8; L_x = 6.1; W_x = 3.8; *spore Q in profile exactly* 1.60; V = 55.55 um^3; *Breadth range* (B_R)= (4-)4.5–5; *mean breadth* ($B_{x)}$ = 4.58 um; *Polar width range* (P_{WR}) = 4.5–5; *mean* ($P_{WX)}$ = 4.9 um; *breadth range* (P_{BR}) = (4-)4.5–5; *breadth mean* (P_{BX}) = 4.45 um; *apical germ pore* distinct; *and* centric; *wall thickness* 0.6 to 1.0 um.

Commentary: Based on the cluster analysis, the epitype collection of *M. horizontalis* clusters next to two collections from USA, California: nos. 9018 and 8560. Sime and Petersen (1999) provide a summary of *M. horizontalis* as interpreted by various authors.

Melanotus textilis Redhead and Kroeger, 1984. Mycologia 76: 868.

CANADA: British Columbia, Vancouver, on fabric of discarded furniture, 9.VII.82, P. Kroeger (DAOM 188219) HOLOTYPE of *M. textilis*. [!]

Morphological Analysis: *Basidiospores in profile* elliptic, or ovoid, or amygdaliform; *in frontal view* elliptic, or oblong, or ovoid; *l x w range* = (6-)6.5–7 x 4–4.5 µm; L_x = 6.28; W_x = 4.0; *spore Q in profile exactly* 1.57; V = 54.55 um^3; *Breadth range* (B_R)= 4–4.5(-5); *mean breadth* ($B_{x)}$ = 4.15 um; *Polar width range* (P_{WR}) = 4.5–4.8(-5); *mean* ($P_{WX)}$ = 4.64 um; *breadth range* (P_{BR}) = (3.8-)4–4.5; *breadth mean* (P_{BX}) = 4.13 um; *apical germ pore* distinct; *and* centric; *wall thickness* 0.6 to 1.0 um

Commentary: Based on the UPGMA cluster analysis the type collection of *M. textilis* is most similar to the type of *A. insidiosus*. See Sime and Petersen (1999) for a discussion of *M. textilis* as circumscribed by various authors.

C. Compatibility Tests

1. Self-crosses

Diagrams of self-crosses are listed in Appendix J with assigned mating types. Micromorphological cultural characteristics were not found to segregate any taxon and are excluded. Self-cross diagnostics are listed by morphological groups as follows:

1) Group I: self-crosses of five collections from Group I all revealed a bipolar mating system. Contact zones were found to be consistently undifferentiated. Clamps were abundant in contact zones in all compatible pairings. Cultural characteristics have been reported by Petersen, 1992c. Appendix G, Figs. 4-8

2) Group II: a self-cross of one collection from Group II revealed a tetrapolar mating system. Contact zones were found to be consistently undifferentiated. Clamps were abundant to scarce in contact zones. Cultural characteristics have been reported by Horak et al, 1990. Appendix G, Fig. 9.

3) Group III: self-crosses of thirteen collections from Group III revealed a tetrapolar mating system. Contact zones were found to be consistently undifferentiated. Clamp connections were copious in the contact zone. Appendix G, Figs. 10 to 23.

Commentary: Walker et al.(1994) also reported on one collection from Group III (no. grw34) as being tetrapolar. Petersen (1992d) utilized no. 3583 (Group III

collection) in a report on the mating system of *M. hepatochorus* from Tasmania, as well as two other collections (nos. 3957 and 4017, not part of this study). In this report (Petersen, 1992d) no. 3583 was not cultured, and nos. 4017 and 3957 exhibited a unifactorial mating system. At the time of this study SBIs from nos. 4017 and 3957 were dead due to improper storage, so Petersen's (1992d) report on a unifactorial system in *M. hepatochorus* can neither be confirmed or refuted.

2. Intercollection, infraspecific pairing experiments.

A total of three unique biological species (= intersterility groups) were identified based on one or more collection pairing sets representing adjacent and disjunct geographic locales. The three identified ISGs correllate with the three morphologicaly defined groups of the UPGMA analysis, and are hereafter included in Groups I-III, respectively. Collections within an ISG were found to be universally compatible within Groups I and II (Appendix H, part B). Within Group III there were three collections that did not display universal compatibility with each other: nos. 7319, grw34, and 8561 (Appendix H). In the latter matings no less than ten pairings out of sixteen per intercollection pairing were found to be incompatible. Results of intercollection pairing experiments are listed in Appendix H.

D. DNA Amplification Fingerprinting

1. Results from 10 octamer and heptamer primers

A total of ten octamer and heptamer primers were used to amplify random sequences from total DNA extracted from 44 collection isolates. Analysis of the PCR reaction products by polyacrylamide gel electrophoresis revealed that each primer

yielded 4-32 bands per collection isolate. Each band in a gel was scored as one DAF locus. Consequently the total number of markers revelead by a specific primer was generally greater than 22 when all primers were compared (Appendix I). Clear amplification profiles were generated and replicated to insure that only reproducable DAF markers were included in the analysis. A total of three groups that correspond to the previously reported morphological and intersterility groupings (Groups I-III) were identifiable only when 10 or more primers were used (Fig. 3).

In Group I, DAF patterns generally did not segregate populations by geographic locale. Isolates from collections made in Puerto Rico and Mexico clustered together, and subclustered based primarily upon substrata preferances, i. e., monocot vs. hardwood. Profiles from two isolates (9323, Malaysia and 4862, Guatamala) displayed a high degree of polymorphism within the Group I cluster that may or not be suggestive of geographic variance. The collections (9323, Malaysia and 4862, Guatamala) are only represented once in this study and derive from Southeast Asia and Central America, respectively. Overall it would appear that the groupings within Group I can be linked to substratum-level differences among members of this cluster, and a much lesser extent to geographic proximity.

DNA-amplification profiles clearly delineated collections of Group II from all others. Within Group II, the solitary Tennessee isolate displayed a higher degree of polymorphism compared to the two North Carolina isolates.

Collections of group III were separated from all other phenons based upon the similarity matrix. Overall, no single cluster segregated in any discernable patterns.



Figure 3. DAF UPGMA phenogram of 44 isolates of *Melanotus*. DAF Phenogram constructed utilizing NTSYS-PC v. 1.04 and is based upon 125 polymorphic loci generated from 10 heptamer and octamer primers. Cophenetic correlation (r) = 0.97. Scale at bottom represents a numerical measure of similarity.

There were a few instances were cluster members shared a substratum (e.g., *Chusqueae* vs. *Nothofagus*); however, overall these collections appear to be highly polymorphic in individual DAF profiles. For example, an isolate from a collection made in the Netherlands growing on wood was in the same phenon as a collection from Tasmania, on a tree fern. Such groupings are unusual based upon prior descriptions (Horak, 1977; Watling and Gregory, 1987) of habitat characteristics for these collections.

IV. CONCLUSIONS

A. Morphology

According to several authors (Horak, 1977; Watling and Gregory, 1987) the collections of *Melanotus* in Group I key out to (3) *M. alpinae*, (17) *M. eccentricus*, and (1) *M. bambusinus* and are seperable on several macro- and micromorphological characters; but specimens under all three names (including type specimens, see below) were found to exhibit similar micromorphological features. I have determined that there is much overlap in the characters used by Horak (1977) and Watling and Gregory (1987) used to segregate these three morphospecies and refer all of the examined specimens in Group I to the priorable name *Agaricus* (*Melanotus*) *alpiniae*. Berkeley's (1856) sanction of the name is found on page 133 of his Decades of Fungi, LI.-LVI.

Commentary: *Melanotus alpiniae* appears to be pan-tropical in distribution, and highly variable in morphological characteristics. Variation in *M. alpiniae* include: 1) forms with unusually large pileus diameter; 2) variation in spore shape and volume; 3) differing mucus depths at the pileus disc; 4) variation in basidium, cheilocystidium, and pleurocystidium average lengths.

Horak (1977) recognized up to five pan-tropical species of *Melanotus* based on morphological grounds. Results of the present study indicate that no single character or suite of morphological characters distinctly segregate taxa within Group I as

described here, but rather represent only variations within a continuum of characters. The following nomenclator for collections within Group I: *M. alpiniae* is offered :

Melanotus alpiniae (Berkeley) Pilát. 1950.Trans. Br. Mycol. Soc. 33: 216.

Basionym: *Agaricus* (*Crepidotus*) *alpiniae* Berkeley, 1856. in: Hook. J. Bot. 8: 133.

≡ *Crepidotus alpiniae* (Berkeley) Saccardo, 1887. Syll. Fung. 5: 886.

= *Melanotus eccentricus* (Murrill) Singer, 1947. Lilloa 13: 87.

≡ *Crepidotus eccentricus* Murrill, 1917. N Am. Fl. 10: 155.

= *Melanotus bambusinus* (Patouillard) Patouillard, 1900. Essai Tax.: 175.

≡ *Crepidotus bambusinus* Patouillard, 1891. J. Bot. Paris 5: 309.

The three collections of Group II are not keyable in either Horak (1977) or Watling and Gregory (1987), but match the published morphological description of *M. defraudatus* by Horak et al (1990). Therefore collections in Group II are refered to *M. defraudatus*.

Commentary: *Melanotus defraudatus* was first reported from North Carolina, USA growing on *Carex* stems. To date this fungus has only been found in the topotype locale and adjacent Tennessee. The results of this study indicate that *M. defraudatus* is morphologically unique from *M. alpiniae*, and Group III collections.

Collections within Group III that key out to *M. textilis*, *M. proteus*, and *M. horizontalis* have been previously reported as belonging to the priorable name *M.*

horizontalis (Sime and Petersen, 1999). Results from this study indicate that collections keying out to *M. patagonicus* and *M. hepatochrous* exhibit similar micromorphological characters to *M. horizontalis*. There is much overlap in the characters traditionally used to segregate these five morphospecies, and the latter two putative taxa are considered facultative synonyms of *M. horizontalis*. Therefore the following nomenclator is offered for *M. horizontalis:*

Melanotus horizontalis (Bulliard.:Fries) Orton, 1984. Notes R. Bot. Gard. Edinb. 41(3): 595.

Basionym: *Agaricus horizontalis* Bulliard, 1787-88. Herbier de la France. Tome 7, fasc. 78-84, pl. 324. [Note: A further description was supplied by Ventenat (1812), Histoire des champignons de la France. Deuxieme partie. p. 573, from Bulliard's manuscripts].

≡ *Naucoria horizontalis* (Bulliard) Quélet, 1873. Mem. Soc. Emul. Montbeliard, ser. II, 5: 347.

≡ *Simocybe horizontalis* (Bulliard) Karsten, 1879. Bid. till Kann. Finlands Natur och Folk XXXII: 420.

≡ *Hylophila horizontalis* (Bulliard) Quélet, 1886. Enchiridion Fungorum, p. 104.

≡ *Galera horizontalis* (Bulliard) Quélet, 1888. Flore mycol. de la France, p. 79.

≡ *Dermimus horizontalis* (Bulliard) Schroeter, 1889. Kryptogamen-Flora von Schlesien. 3(1), Pilze 1: 581.

≡ *Phaeomarsmius horizontalis* (Bulliard) Kühner ex Singer, 1950. Trudy

botanicheskogo insituta V.L. Komarova, ser. II, 6: 482. [transliterated]

= *Agaricus proteus* Kalchbrenner. apud Thümen, 1876. Flora 59: 424.

≡ *Claudopus proteus* (Kalchbrenner) Saccardo, 1877. Syll. Fung. 5: 734.

≡ *Crepidotus proteus* (Kalchbrenner *apud* Thümen.) Pilát, 1950. Trans. Brit. mycol. Soc. 33:231.

= *Agaricus hepatochrous* Berkerley, 1848. Hook. J. Bot., 7: 754.

≡ *Melanotus hepatochrous* (Berkeley) Singer, 1951. Sydowia 5: 472.

≡ *Melanotus insidiosus* (Berkeley) Pegler, 1964. Austr. J. Bot. 13: 336.

= *Agaricus (Crepidotus) insidiosus* Berkeley, 1848. Hook. J. Bot., 7: 754

= *Agaricus cassiaecolor* Berkeley *apud* Saccardo, 1887, Syll. Fung. 5: 889; 1891, Syll. Fung. 9: 1891.

≡ *Melanotus cassiaecolor* (Berkeley) Singer, Sydowia 15: 70. 1950.

≡ *Agaricus turbidulus* Berkeley. in Herb. , sec. Cooke in Grevillea 9: 148. 1881.

= *Melanotus patagonicus* Singer, 1969. Beih. Nova Hedw. 29: 258.

= *Melanotus textilis* Redhead and Kroeger, 1984. Mycologia 76: 868.

Commentary: *Melanotus horizontalis* appears to be cosmopolitan in its distribution, being found in both hemispheres. This group of morphologically plastic fungi includes the following variable forms: 1) forms with unusually large pileus diamters; 2) variation in spore length range and volume that appears to be geographically correlleated; 3) differing mucus depths at the pileus disc; 4) ranges

and averages of basidia, cheilocystidia, and pleurocystidia characteristics that do not appear to be correlated in any ecological manner.

Horak (1977) recognized up to five different temperate species of *Melanotus* solely on morphological grounds. The results of this study indicate that no single character or suite of characters delineated unique taxa within *M. horizontalis* as described here. Instead it appears that members of the *M. horizontalis* group represent only variations within a continuum of morphologically plastic characters. Spore length averages may be correlated to geographic locale within taxa that are found in North America , Europe and AustralAsia vs. those taxa found in South America.

1. Morphotaxonomic Discussion

The morphological characters that have been traditionally used to delineate taxa within the genus *Melanotus* (Horak, 1977; Watling and Gregory, 1987; and Singer, 1986) are demonstrably ambiguous, and appear to be of limited value in the identification of morphological species. However, species could be identified based upon characters (Appendix B) not utilized by the latter authors. Results of morphological studies within the studied collections of *Melanotus* indicate that at least three species can be recognized. The species correspond to: 1) *M. alpiniae*; 2) *M. defraudatus*; 3) *M. horizontalis*. These taxa represent unique morphological groups, wherein wide variation in morphological characters may be found. That the taxa appear to be genetically distinct (see below) further supports the distinction of Groups I-III as morphospecies.

The results of the UPGMA phenograms of all specimens display a general trend wherein taxa that share the greatest degree of similarity can be found to represent the same overall geographic locale. Collections that were initially identified using dichotomous keys (Horak, 1977; Watling and Gregory, 1987; and Singer, 1986) did not cluster together, but rather were found to intergrade irrespective of geographic locale.

Altogether, the morphological analysis results within the three groups detected clusters composed principally of collections from the same geographic region. This pattern appears to represent the process of morphological divergence among three large populations predominantly allopatric in geographic distribution.

B. Compatibility Experiments

1) Self-crosses

Collections of *M. alpiniae* were all found to be bipolar. These results were consistent with Petersen's (1992a) published results.

Collections of *M. defraudatus* exhibited a tetrapolar mating system, which also supported results by Petersen (1992b).

Collections of *M. horizontalis* all exhibited a tetrapolar mating system, which supports Walker et al's. (1994) report on *M. textilis*. Petersen (1992a) reported *M. hepatochorus* to possess a bipolar mating system, which was not confirmed, because the isolates used by Petersen (1992a) were not available for use in this study.

Within the Pacific-Northwest collections of *M. horizontalis*, several appeared to show some degree of amphithallism, or the results are a consequence of improper

harvesting techniques (i.e. harvesting of two SBIs as one isolate). It is difficult to say, however, as all SBIs were checked for ploidy number: 1) under 400X power (microslide mount of mycelia from random samples of Petri plate mycelia); 2) under 200X dry mount; and 3) randomly excised tissue viewed under epifluorescence at 1000X-2250X. Petersen (1995a) provided a review and discussion on amphithallism in certain agarics. It is difficult to say if the mating results within this complex are a consequence of amphithallism or are artifacts of the harvesting technique.

2) Infraspecific and interspecific pairing analysis

Overall mating within ISGs revealed complete intercompatibility (Appendix H, parts B and C) with only a few instances of low-level interINincompatibility. Other workers (Boidin, 1971, 1986; Hallenberg, 1991; Gordon and Petersen, 1992; Petersen, 1995) have discussed partial compatibility of geographically local and distant populations of hymenomycetes. It may be that within a geographic region reduced compatibility is due to shared mating alleles. This is most likely the case within *M. horizontalis*, as collections made within relatively small geographic locales demonstrated low-levels of incompatibility. Typically, pairings within an ISG group were compatible as mating type genes are multiallelic, prevalent, and are randomly distributed within a population (Raper, 1966; Ullrich, 1977).

Based on the sum of the intercompatibility data a total of three biological species (= intersterility groups) can be recognized. Theses three multiple isolate intersterility groups represent the following taxa within *Melanotus*: *M. alpiniae*, *M. defraudatus*, and *M. horizontalis*.

Some systematists have included several morphospecies names under a single biological species. For example, McCleneghen (1996) in a study on the *Pholiota alnicola* complex defined only a single biological species within this complex, while Smith and Hesler (1968) had originally reported up to seven taxa. Chang and Mills (1992) demonstrated that several morphotaxa within the *Psilocybe subaeuriginosa* complex represented a single biological species based upon mating data and electrophoretic profiles. Vilgalys (1986, 1991) has demonstrated that while European and eastern North American collections of *Collybia dryophila* were morphologically different, they were sexually intercompatible. These data can aid in circumscribing otherwise morphologically ambiguous fungi.

Several other authors have reported on comparable instances of inter- and intracontinental compatibility among collections that share an overlapping range of morphological characteristics (Petersen and McCleneghan, 1995, for *Pleurotopsis*; Petersen, 1994, for *Xerula*; Petersen and Bermudes, 1992, for *Panellus*; Korhonen, 1978, for *Heterbasidion*; Boidin, et. al., 1980, for *Vararia*; Bresinksy et. al., 1987, for *Pleurotus*; Duncan and MacDonald, 1967, for *Auricularia*; Petersen and Wu, 1991, for *Clavicorona*).

Other studies (Anderson and Ullrich, 1979: for *Armillaria*; Petersen, 1995; for *Pleurotus*; *Heterbasidion* (Korhonen, 1978)) have shown just the opposite: that a single morphospecies was found to contain several biological species. Many species of *Armillaria* occur sympatrically, Rizzo and Harrington (1993) report on several species of *Armillaria* inhabiting the same tree. Many plant pathologists considered the

different species of *Armillaria* to represent one species: *A. mellea*. It was not until barriers to gene flow were identified (Anderson and Ulrich, 1978) that *A. mellea* was split into several taxa.

In general, the following authors have challenged the biological species concept as conceived by Mayr (1942, 1963) and Dobzhansky (1937): Donoghue, (1985); Mishler, (1985); Mishler and Donoghue, (1982), Perkins, (1994). While acknowledging that the presence of clamp connections and dikaryons in intercollection crosses (i.e., intercompatibility) is not synonymous with interfertility, such observations do indicate shared or potentially shared gene pools, the cornerstone of the biological species concept. The fact that putative hybrids from *M. alpinae, M. defraudatus*, and *M. horizontalis* derived from intercollection crosses were stable in repeated clonal transfers, and formed extensive mycelial mats also suggest a close genetic relationship (Boidin, 1986). The fact that the three morphotaxonomic groups are represented by a single intersterility group each suggests that genetic exchange has been occuring within the populations, and this may account for the overall range of phenotypic plasticity exhibited by the groups.

Because the intercompatibility experiments check only for production of a viable dikaryon, the ability of these intercompatible crossings to produce viable basidiomata is uncertain. Based on unpublished data (Sime, Psurtsava, and Petersen), however, there was a low incidence of hybrid basidioma production *in vitro* in *M. alpiniae* between collections 9323 (Malaysia), 3822et (Mexico) and 9305 (Puerto Rico). These basidiomata were found to exhibit a morphology identical to *M. alpiniae*, but were not

followed for viable basidiospore production. Such findings only serve to reinforce the contention that these disjunct collections share a similar gene pool.

The fact that these widespread populations i.e. groups with multiple disjunct collections (*M. alpiniae*, *M. horizontalis*) can interbreed raises questions concerning gene flow. According to Redhead (1989), evidence of long-distance dispersal of basidiospores appears to be limited. Long-distance dispersal of basidiospores could account for sexually intercompatible, disjunct populations. However, recent evidence (Nordén and Larsson, 2000) and previous reports (Goudriaan, 1991; Nordén, 1997) have demonstrated that dispersal of lignicolous fungal propagules can occur over distances of one kilometer. While acknowledging that even this distance may not account for observed intercontinental compatibility, it does support the hypothesis that long-distance dispersal of basidiospores can and does occur.

Alternatively, if gene flow does not occur naturally, it is difficult to interpret the matings in the distinctly allopatric populations. Just because the collections are intercompatible in the laboratory does not neccesarily mean the individuals can interbreed in the biome (Harrington and Rizzo, 1999). If the populations of *Melanotus* are the product of human-mediated activities, the utilized collections may not represent endemic organisms. Thus the results of the mating data may not accurately reflect the process of speciation and gene flow in endemic populations.

C. DNA amplification fingerprinting

In *M. horizontalis*, the isolates clustered based upon substratum and geolocale, but to a much lesser extent than seen in *M. alpiniae*. For example, in one terminal cluster

two taxa were found together (v153: Netherlands, on wood, and 3583: Tasmania, on tree fern rachis) that represented disjunct collections and occurred on different substrata. Conversely, isolates from Argentina showed similar fingerprinting profiles and substratum choices, i.e, *Nothofagus* vs. *Chusquea*. Overall, hardwood vs. gymnosperm vs. monocot taxa appear to be molecularly more dissimilar to each other.

Isolates of *M. defraudatus* clustered together and were basal to the *M. alpiniae* phenon. All collections of *M. defraudatus* were graminicolous, whereas isolates of *M. alpiniae* utilized both monocot and diocot substrata. *Melanotus defraudatus* isolates clustered irrespective of geographic locale, with isolates from North Carolina having more bands in common with one isolate from Tennessee than another isolate from North Carolina.

Another possible source of the variation is that DAF is not suitable for differentiating among these taxa, as they represent distinct biological species. Typically, the resolving power of DAF (i.e., ability of the technique to distinguish between samples) is best suited for infraspecific variation (R. N. Trigiano, pers. com.). While DAF is suitable for distinguishing populations within a biological species, it may not be useful for resolving between morphological and biological species in *Melanotus*. In addition, DAF is still a relatively new technique, and has not been utilized as much as other arbitrary PCR based techniques. It may contain artifacts that hinder accurate analysis (Coppenolle, 1993).

D. Summary

In all previous studies on *Melanotus* much reliance was placed on morphological characteristics as the basis for taxonomy within this genus of dark-spored, pleurotoid fungi (Horak, 1977; Gregory and Watling, 1987; Singer, 1973; and Pilát, 1950). Analysis of 13 type specimens and 45 collections of *Melanotus* indicate that there is a high degree of phenotypic plasticity in the collections studied. These conclusions are not similar to the taxonomy by other authors (Horak, 1977; Watling and Gregory, 1987; Singer, 1973; Pilát, 1950), nor were the results of the mating and DNA analysis congruent with those authors' schemes.

The morphological characters that basidiomata of *Melanotus* exhibit are very limited, yet they have been shown to be of some taxonomic value, in conjunction with biological and molecular data. Traditional morphological characters appear to represent overlapping phenotypic plasticity, and are not species-diagnostic.

Use of a biological species concept in *Melanotus* may have the most promise for delineating otherwise morphologically ambiguous taxa. Based on these data it appears that the three studied populations of *Melanotus* have achieved some form of genetic isolation from each other. Intraspecific compatibility measurements indicate there may be low levels of speciation occurring, as collections within a geographic locale were found to show compatibilty depression (Petersen and Hughes, 1999).

Similar instances of compatibility depression have been linked to speciation events in plants, particularly as a result of hybridization. Introgressive hybridization, where genetic material is exahanged between hybridizing taxa can lead to the melding

of two hybridizing morphospecies, leading to a highly variable array of populations (Arnold, 1994). Such events can strengthen the barriers to gene flow, creating novel genotypes that may be better adapted to unusual habitats. Hybridization in plants has been suggested to increase intraspecific genetic diversity (Andersen, 1948), or lead to the reinforcement or breakdown of reproductive barriers (Ellstrand, et al. 1993; Levin, et al. 1996).

Reproductive isolation is generally considered to be a definitive indication of speciation, which present study ISG data indicate (Korhonen, 1978). The mating data presented here further suggests that pairs of intercompatible, allopatric populations may share some, built not all alleles conferring the inability to produce basidioma. Over time, most of these common alleles could be lost in the various lineages, resulting in the allopatric groups being intersterile. The wide range of morphological characters seen in an intersterility group may be attributable to genetic drift, or other factors in isolated populations, such as selction for particular substratum niches.

A molecular species concept based on DAF in *Melanotus* appears to have less value than a biological species concept. Genetic differences as measured by DNA fingerprinting did not correlate with any morphospecies concepts of Horak, 1977, Watling and Gregory, 1987, Singer, 1973, or Pilát (1950). Overall banding patterns differed between Groups I-III, but isolates within an ISG were found to share similar electrophoretic profiles. The fingerprinting technique utilized herein appears to be able to generally segregate collections within an intersterility group based upon geographic locale, and to a lesser extent by substratum characteristics.

In conclusion, the result of the mating, morphological, and DAF data indicate that all studied collections can be grouped into three multiple-collection intercompatibility groups. In the circumscription of species within *Melanotus* it appears that the use of multiple data sets i.e., morphology, mating studies, and molecular profiling may aid in the defining of natural groups in this genus.

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APPENDICES

APPENDIX A: COLLECTIONS UTILIZED FOR MORPHOLOGICAL, COMPATIBILITY, AND DAF ANALYSES. METHOD OF USE: SX= SELF-CROSS, IX = INTERCOMPATIBILITY CROSS, D = DAF, M = MORPHOLOGY.

Group I: *Melanotus alpiniae*

BRAZIL: PANURÉ, Jan. 1853, *R. Spruce*, on *Alpiniae aromatica*, Spruce 114, (K(M) 57577) **HOLOTYPE** of *C. alpiniae*, M. **GUATAMALA**: DPTO. ESCUINTLA, 1. VII.92, *Ronald H. Petersen*, monocot debri, Field no. 4862, (TENN 51161) SXDM, 1,4,19,13. **JAMAICA**: KINGSTON, East of Hope Gardens, 12.VII.1908, *WA Murrill*, on dead herbaceous stems, WA Murrill 21, **HOLOYTPE** of *C. eccentricus* M. **MEXICO**: CHIAPA, Cacolahatua, Mixcum, 15 01' 584 N 092 08' 450W, 18.X.97, *Ronald H. Petersen*, banana petiole, Field no. 3872, (TENN 55846) IXDM; CHIAPA, Cocolahata; 15 01.584'N 092 08.450'W, 18.X.97, *Ronald H. Petersen*, hardwood post, Field no. 3879, (TENN 55853) IXDM, 15,16,17,20; VERACRUZ, Catamaco, V.N.A.M. Bio Station, 24.X.91, *Ronald H. Petersen*, Spring Palm, Field no. 4383, (TENN 50457) SXIXDM, 4,8,12,20; VERACRUZ, Caotepec, 14.VII.93, *Ronald H. Petersen,* on banana, Field no.6273, (TENN 52927) IXDM, 2,4,9,15; VERACRUZ, Caotepec, 14.VII.93, *Alexander-King-Luz*, on rotten wood, Field no. 6268, (TENN 52924) IXDM; HIDALGO, 20 58' 57N 098 40' 05W, 19.VI.96, *A. Estrada*, on stick, Field no. 3822et, (TENN 58561) SXIXDM,2,4,7,12. **PUERTO RICO**: Caribbean National Forest, Bosque Carite, Cayey, 2.XI.89, *Jean Lodge*, rotten palm, Field no. 2443, (TENN 48727), SXDM, 1,3,8,10; Caribbean National Forest, Junquillo Mts, El Verde Bio Station, 7.X1.89, *Ronald H. Petersen*,

rotting palm, Field no. 2499, (TENN 48744) DM, 4,8,6,10; Caribbean National Forest, Junquillo Mts, El Verde Bio Station, 3.XII.90, *Scott Gordon*, banana leaves, Field no. 3446, (TENN 48859) DM; Caribbean National Forest, Forestal Res. Carité, 8.XII.90, *Ronald H. Petersen*, rotten palm, Field no. 3487, (TENN 48860) SXM, 1,4,2,3; Caribbean National Forest, Forestal Res. Carité, 8.XII.90, *Ronald H. Petersen*, rotten palm, Field no. 3488, (TENN 48861); Caribbean National Forest, El Verde Bio Station, 9.VI.98, *AD Sime* palm culms, , Field no. 9306, (TENN 56325) IXDM; Caribbean National Forest, El Toro Rec. Trail, Luquio Forest, 18 16' 49N 063 51' 31W, 11.VI.98, *Tim Baroni*, on palm pulvini, Field no. 9310, (TENN 56327) IXDM; Caribbean National Forest, 11.VI.98, *AD Sime*, on palm adventitious roots, Field no. 9311, (TENN 56328) IXDM ; Caribbean National Forest, El Verde Bio Station, 9.VI.98, *AD Sime*, palm culms, Filed no. 9305, (TENN 56324) IXDM, 8,10,16,17; Caribbean National Forest, El Toro Rec. Trail, Luquio Forest, 18 16' 49N 063 51' 31W, 2015' elev., 11.VI.98, *AD Sime*, palm culms, Field no. 9312, (TENN 56329) IXDM; Caribbean National Forest, Big Tree Trail, 11.VI.98, on palm frond, *AD Sime*, Field no. 9315, (TENN 56332) IXDM, 3,4,17,18; Caribbean National Forest, Verda Mt., Britton Trail, 18 17' 55 N 065 47' 29W, 11.VI.98, *AD Sime*, palm frond, Filed no. 9316, (TENN 56333) IXDM;

Group II: *Melanotus defraudatus*

NORTH CAROLINA, Macon Co., Blue Valley, swamp grass, 30.VIII.89, *Ronald H. Petersen* Field no. 2230, (TENN 48119), **HOLOTYPE** of *M. defraudatus*;

NORTH CAROLINA, Macon Co., Blue Valley Rd., on grass, 19.VI.92, *Coleman McCleneghan*, Field no. 5124, (TENN 52662) SIXMD, 1,8,9,10; TENNESSEE, Knox Co., Strawberry Plains, grass lawn, 26.VI.98, *Ed Lickey*, Field no. 9317, (TENN 58547) DM; TENNESSEE, Knox Co., Halls, Ft. Sumter Rd, grass clumps, *AD Sime*, 21.VIII.97, 8594, (TENN 58548) SXIXM, 9,18,22,42;

Group III: *Melanotus horizontalis*

ARGENTINA: Prov. Nuequen, Puerto Manzano, 17-III-1963, *R. Singer, Ad lignum putrescente*, Singer no. M 3060, (BAFC 23963), **HOLOTYPE** of *M. patagonicus* M; Prov. Chubut, Parque Nacional de Los Alerces, south shore of Lago Verde, 9-V-96, *A. D. Sime*, *Chusquea culeou*, Field no. 8614, (TENN 54953) SXIXDM, 1,2,8,15; Prov. Chubut, Parque Nacional de Los Alerces, south shore of Lago Verde, 9-V-96, *A. David Sime*, *Chusquea culeou*, Field no. 8619, (TENN 54958) IXDM; Prov. Nuequen, Villa d'Angustura, 5K past Aquas Blancas, 16-V-96, *A. David Sime*, *Nothofagus dombeyii*, Field no. 8653, (TENN 55375) IXDM, 1,5,7,11; Prov. Rio Negro, Parque Nacional de Nahuel Huapi, Puerto Blest, road to Lago Frias, 17-V-96, *A. David Sime*, *Nothofagus dombeyii*, Field no 8656, (TENN 55378) SXIXDM, 16,7; Prov. Rio Negro, Parque Nacional de Nahuel Huapi, Puerto Blest, road to Lago Frias, 17-V-96, *A. David Sime*, *Nothofagus dombeyii*, Field no 8657, (TENN 55379) sxixdm, 9,5;Prov. Nuequen, Parque Nacional de Lannin, north shore of Lago Lacar to Paso Hua Hum, 19-V-96, *A. David Sime*, *Chusquea culeou*, Field no. 8661, (TENN 55383) IXDM, 11,5; **AUSTRALIA**: TASMANIA, on wood, Herb. Berk no.

756, [as Gunn, No. 1787, May, 1845, Berk., Lond. J. Bot 7:574], K (M) 48937, TASMANIA, Penquite, on bark, May, 1845, with no. 1787, K (M) 57578, **HOLOTYPE** of *M. insidiosus* M. ; TASMANIA, on wood, *W. Archer*, K (M) 57579 [as] *M. cassiacolor* **LECTOTYPE** of *A. cassiaecolor* M; **HOLTYPE** of *M. hepatochrous*, M; TASMANIA, on wood, K (M) 57580, **HOLOTYPE** of *M. turbidulus* M; TASMANIA, Mt. Wellington, 25.V.91, *Ronald H. Petersen*,dead *Dicksonia* fronds and rachis, Field no. 3583, (TENN 50137) SXIXDM, 14,17,21,24; TASMANIA, on wood, Archer, K (M) 60101 as *M. cassiaecolor* **PARATYPE** of *A. cassiaecolor*,M; **CANADA**: BRITISH COLUMBIA, Vancouver, on fabric of discarded furniture, 9.VII.82, *P. Kroeger* (DAOM 188219) **HOLOTYPE** of *M. textilis* M; **MALAYSIA**: NORTH BORNEO, Sabah, Danum Valley, ?/?/98, *Tom Læssöe*, woody stick, Field no. 9323, (TENN 58477) SXIXDM, 1,4,7,9. **NETHERLANDS**: Ryswyk, landgood, 10.IX.96, "Huys teWerve", wood, *Hees Horst*, v153, IXDM, 4,8,11,15; **NEW ZEALAND**, North Island, 28.V.94, *Ronald H. Petersen*, tree fern rachis, Filed no. 7156, (TENN 54033) IXDM, 3,4,10,11; **UNITED KINGDOM**: ENGLAND, Essex, Monks Wood, Epping Forest, 10.X.82, *Martin Gregory*, on Beech stump, Orton 5316 (E 00037827) **EPITYPE** of *M. horizontalis* M; SCOTLAND, vic. Pitlochry, Kindrogen, VIII.97, *Ronald H. Petersen*, on *Betula* sp., Field no. 6964 (TENN 56287) SXIXDM, 16,1719,20; SCOTLAND, vic. Pitlochry, Kindrogan, 31.VIII.97, *Martyn Ainsworth* on *Picea* sp., Field no. 6963 (TENN 56288) SXIXM, 14,16,17,20; SCOTLAND, vic. Pitlochry, Kindrogen, 5.IX.97, *Ronald H. Petersen*, on conifer logs, Field no. 3862, (TENN

56290) SXIXD, 14,18,19,20. **UNITED STATES**: CALIFORNIA Humboldt Co., Orick, Lost Man Creek area, 16.X.93, *Ronald H. Petersen*, on *Ceanothus foliosus*, Field no. 7319, TENN 54933 SXIXDM, 5,11,21,29; CALIFORNIA, Humboldt Co., Patricks Point State Park, XII-19-96, *Sarah Bergemann*, on *Picea sitchensis*, Field no. 8560, (TENN 55129) IXDM, 7,10,11,18; Patricks Point State Park, XII-19-96, *Sarah Bergemann*, on *Picea sitchensis*, Field no. 8561, TENN 55130 IXDM, 5,7,20,21; Humboldt Co., Prairie Creek State Park, Davison Rd., 21.XI.96, *Ronald H. Petersen*, on *Sambucus* sp., Field no. 9037, (TENN 55724) SXIXDM, 14,16,17,20; Mendocino Co., Van Damme State Park, 24.XII.91, *Glen Walker*, on hardwood, GRW 34, SXIXDM, 25,27,45,46;. Trinity Co., Rt. 299, Grey's Falls campground, on wood, *Ronald H. Petersen*, 9018, (TENN 58559) IXDM, 7,10,11,18; WASHINGTON, King Co., Seattle, U. W., 4.X.92, *Ronald H. Petersen*, on hardwood, Field no.5734 (TENN 52573) IXDM, 5,6,11; WASHINGTON, Snohomish Co., 15.XII.96, *Brandon Matheny*, conifer branch, Field no. PBM 772, (TENN 58550) SXIXDM, 11,14;. **SOUTH AFRICA**: Somerset-East, Promont: bonae spei. Jan. 1876, in ligno humido, fabrefacto, clathrato, vitifero, hortensi prope, Kalchbrenner, Leg. P. MacOwan; Exsic. no. 503, (DAOM **ISOTYPE** of *A. proteus*) (FH **LECTOTYPE** of *A. proteus*) M; **VIETNAM**: KE SO, Tonkin, on putrid Bambusae, 28.VIII.1890, *H. Bon*, 4464/HN, **HOLOTYPE** of *C. bambusinus* M.

APPENDIX B: LIST OF MICROMORPHOLOGICAL AND MACROMORPHOLOGICAL CHARACTERS FOR DELTA

*SHOW Melanotus taxa Character list
*CHARACTER NOTES
*CHARACTER LIST
#1. <species, abbreviated author and literature citations>/

#2. <country, state, county, province, general locale, collector, date, field number, herbarium acronym and number, type status>/

#3. <specific substratum> \b{}Substratum\b0{}:/

#4. \b{}Macromorphology\b0{}/
1. as follows:/
2. not reported by collector./

#5. \b{}Pileus\b0{} <mm in diam.>/
mm in diam./

#6. <pileus> shape <side view> in youth/
1. conic/
2. campanulate/
3. convex/
4. parabolic/
5. applanate/
6. uplifted/
7. umbonate/
8. broadly umbonate/
9. acutely umbonate/
10. cuspidate/
11. shallowly depresses/
12. deeply depressed/
13. umbilicate/
14. infundibuliform/

#7. <pileus shape side view> in adult basidiomata/
1. later conic/
2. later campanulate/
3. later convex/
4. later parabolic/
5. later applanate/
6. later uplifted/
7. later umbonate/

8. later broadly umbonate/
9. later acutely umbonate/
10. later cuspidate/
11. later shallowly depressed/
12. later deeply depressed/
13. later umbilicate/
14. later flabelliform/
15. later infundibuliform/
16. later hemispherical/
17. unchanged/

#8. <pileus shape in top view> at first/
1. ovoid in profile/
2. flabelliform in profile/
3. petaloid in profile/
4. spathulate in profile/
5. conchate in profile/
6. dimidiate in profile/

#9. <pileus shape in top view> later <in age>/
1. becoming ovoid/
2. remaining ovoid/
3. becoming flabelliform/
4. remaining flabelliform/
5. becoming petaloid/
6. remaining petaloid/
7. becoming spathulate/
8. remaining spathulate/
9. becoming conchate/
10. remaining conchate/
11. becoming dimidiate/
12. remaining dimidiate/

#10. <pileus> surface <appearance> in youth/
1. shiny/
2. dull/
3. sericeous/
4. dry/
5. glutinous/
6. oily/
7. viscid/
8. subviscid/
9. hygrophanous/

#11. <pileus surface appearance in adult basidiomata> in age/
1. becoming shiny/
2. remaining shiny/
3. becoming dull/
4. remaining dull/
5. becoming sericeous/
6. remaining sericeous/
7. becoming dry/
8. remaining dry/
9. becoming glutinous/
10. remaining glutionous/
11. becoming oily/
12. remaining oily/
13. becoming viscid/
14. remaining viscid/
15. becoming subviscid/
16. remaining subviscid/
17. becoming hygrophanous/
18. remaining hygrophanous/

#12. <pileus surface in age> texture\par{} /
1. smooth/
2. scrobiculate/
3. alveolate/
4. lacunose/
5. rimose/
6. areolate/
7. rivulose/
8. rugulose/
9. rugose/
10. felty/

#13. <pileal surface hyphal associations at> disc <in adult basidiomata>/
1. glabrous/
2. glabrescent/
3. atomate/
4. micaceous/
5. superficial/
6. innate/
7. pruinose/
8. furferaceous/
9. granulose/
10. fibrillose/
11. rimose-fibrillose/

12. virgate/
13. hoary/
14. downy-wooly/
15. downy-fibrillose/
16. floccose/
17. tomentose/
18. matted tomemtose/

#14. <pileal surface hyphal associations> in between disc and margin <in adult basidiomata>/
1. glabrous/
2. glabrescent/
3. atomate/
4. micaceous/
5. superficial/
6. innate/
7. pruinose/
8. furferaceous/
9. granulose/
10. fibrillose/
11. granulose/
12. rimose-fibrillose/
13. virgate/
14. hoary/
15. downy-wooly/
16. floccose/
17. tomentose/
18. matted-tomentose/

#15. <pileus margin> margin in youth/
1. inrolled/
2. incurved/
3. decurved/
4. plane/
5. uplifted/
6. wavy/

#16. <pileus margin> in age/
1. becoming inrolled/
2. remaining inrolled/
3. becoming incurved/
4. remaining incurved/
5. becoming decurved/
6. remaining decurved/

7. becoming plane/
8. remaining plane/
9. becoming uplifted/
10. remaining uplifted/
11. becoming wavy/
12. remaining wavy/

#17. <pileal surface associations> margin surface <in adult basidomata>/
1. glabrous/
2. glabrescent/
3. atomate/
4. micaceous/
5. superficial/
6. innate/
7. pruinose/
8. furferaceous/
9. granulose/
10. fibrillose/
11. rimose-fibrillose/
12. virgate/
13. hoary/
14. downy-wooly/
15. downy-fibrillose/
16. floccose/
17. tomentose/
18. matted-tomentose/

#18. <shape of margin> in youth/
1. crenate/
2. crisped/
3. undulating/
4. eroded/
5. rimose/
6. appendiculate/
7. plicate-striate/
8. entire/

#19. <shape of margin> in age/
1. becoming crenate/
2. remaining crenate/
3. becoming crisped/
4. remaining crisped/
5. becoming undulated/
6. remaining undulated/

7. becoming eroded/
8. remaining eroded/
9. becoming rimose/
10. remaining rimose/
11. becoming appendiculate/
12. remaining appendiculate/
13. becoming entire/
14. remaining entire/

#20. <pileus margin> with a/
1. pellucid appearance/
2. translucent-striate appearance/
3. sulctae appearance/
4. plicate-striate appearance/
5. tuberculate-striate appearance/
6. non-striate appeance/

#21. pileal disc <color>/
1. off-white (1A1)/
2. vivid-yellow to grey-yellow (3A-B, 8-3)/
3. vivid-grey to olive-grey (3B-F, 2)/
4. deep-yellow to pale-yellow (4A, 8-2)/
5. greyish-yellow to light-blond (4B-C, 8-2)/
6. olive-brown (4D-F, 8-3)/
7. brown-grey (4D-F, 2)/
8. Orange-white (5A-2)/
9. golden-yellow (5B, 7)/
10. greyish-orange (5B, 6.5-3)/
11. brown-yellow to brown-orange (5C, 8-3)/
12. yellow-brown to dark-blond (5D, 8-4)/
13. brown (5E-F, 8-4)/
14. light-brown (6D, 6-4)/
15. grey-brown (6F, 8-3)/
16. dark-brown (7E-F, 8-4)/
17. red-brown (8D-E, 8-4)/

#22. <pileal> in-between <color>/
1. off white (1A1)/
2. vivid yellow to grey yellow (3A-B, 8-3)/
3. yellow-grey to olive-grey (3B-F, 2)/
4. deep yellow to pale yellow (4A, 8-2)/
5. greyish yellow to light blond (4B-C, 8-2)/
6. olive-brown (4D-F, 8-3)/
7. brown-grey (4D-F, 2)/

8. orange-white (5A-2)/
9. golden yellow (5B, 7)/
10. greyish orange (5B, 6-3)/
11. brown-yellow to brown-orange (5C, 8-3)/
12. yellow-brown to dark-blond (5D, 8-4)/
13. brown (5E-F, 8-4)/
14. light -brown (6D, 6-4)/
15. grey-brown (6D-F, 3)/
16. dark brown (7E-F, 8-4)/
17. red-brown (8D-E, 8-4)/

#23. <pileal> margin <color>/
1. off white (1A1)/
2. vivid yellow to grey-yellow (3A-B, 8-3)/
3. yellow grey to olive-grey (3B-F, 2)/
4. deep yellow to pale-yellow (4A, 8-2)/
5. greyish yellow to light-blond (4B-C, 8-2)/
6. olive-brown (4D-F, 8-3)/
7. brown-grey (4D-F, 2)/
8. orange-white (5A-2)/
9. greyish orange (5B, 6-3)/
10. golden-yellow (5B,7)/
11. brown-yellow to brown-orange (5C, 8-3)/
12. yellow-brown to dark-blond (5D, 8-4)/
13. brown (5E-F, 8-4)/
14. light brown (6D, 6-4)/
15. grey-brown (6D-F, 3)/
16. dark-brown (6F, 8-3)/
17. dark-brown (7E-F, 8-4)/
18. red-brown (8D-E, 8-4)/

#24. \b{}Lamellae\b0{} <attachement>/
1. adnate/
2. adnexed/
3. subdecurrent/
4. decurrent/
5. sinuate/
6. seceding/
7. emarginate/
8. arcuate-decurrent/

#25. <lamellae width> /
1. thin/
2. medium/

3. thick/

#26. <lamellae shape> in tangential section/
1. equal/
2. clavate/
3. obclavate/

#27. <lamellae spacing>/
1. distant/
2. subdistant/
3. close/
4. crowded/

#28. <lamellae> margin at first/
1. marginate/
2. smooth/
3. fimbriate/
4. serrate/
5. serrulate/
6. crenate/
7. eroded/
8. crisped/
9. undulating/
10. entire/

#29. <lamellae margin> in age/
1. becoming marginate/
2. remaining marginate/
3. becoming smooth/
4. remaining smooth/
5. becoming fimbriate/
6. remaining fimbriate/
7. becoming serrate/
8. remaining serrate/
9. becoming serrulate/
10. remaining serrulate/
11. becoming crenate/
12. remaining crenate/
13. becoming eroded/
14. remaining eroded/
15. becoming crisped/
16. remaining crisped/
17. becoming undulated/
18. remaining undulated/

19. becoming even/
20. remaining even/

#30. <lamellae margin color> in youth/
1. concolorous with pileus/
2. off white (1A1)/
3. vivid yellow to grey-yellow (3A-B, 8-3)/
4. yellow-grey to olive grey 93B-F, 2)/
5. deep yellow to pale-yellow (4A, 8-2)/
6. greyish yellow to light blond (4B-C, 8-2)/
7. olive-brown (4D-F, 8-3)/
8. brown-grey (4D-F, 2)/
9. golden yellow (5B, 7)/
10. greyish-orange (5B, 6-3)/
11. brown-yellow to brown-orange (5C, 8-3)/
12. yellow-brown to dark blond (5D, 8-4)/
13. dark-brown (7E-F, 8-4)/
14. red-brown (8D-E, 8-4)/

#31. <lamellae margin color> in age/
1. also concolorous with pileus/
2. off white(1A1)/
3. becoming vivid yellow to grey-yellow (3A-B, 8-3)/
4. becoming yellow-grey to olive-grey (3B-F, 2)/
5. becoming deep-yellow to pale-yellow (4A, 8-2)/
6. becoming greyish yellow to light blond (4B-C, 8-2)/
7. becoming olive-brown (4D-F, 8-3)/
8. becoming brown-grey (4D-F, 2)/
9. becoming golden-yellow (5B, 7)/
10. becoming greyish orange (5B, 6-3)/
11. becoming brown-yellow to brown-orange (5C, 8-3)/
12. becoming yellow-brown to dark blond (5D, 8-4)/
13. becoming brown (5E-F, 8-4)/
14. becoming light brown (6D, 6-4)/
15. becoming grey-brown (6D-F, 3)/
16. becoming dark-brown (6F, 8-3)/
17. becoming dark brown (7E-F, 8-4)/
18. becoming red-brown (8D-E, 8-4)/

#32. <lamellae> face <color>/
1. concolorous with pileus/
2. off white (1A1)/
3. vivid yellow to grey-yellow (3A-B, 8-3)/
4. yellow-grey to olive-grey (3B-F, 2)/

5. deep yellow to pale yellow (4A, 8-2)/
6. greyish yellow to light blond (4B-C, 8-2)/
7. olive-brown (4D-F, 8-3)/
8. brown-grey (4D-F, 2)/
9. golden-yellow (5B, 7)/
10. greyish orange (5B, 6-3)/
11. brown-yellow to brown-orange (5C, 8-3)/
12. yellow-brown to dark blond (5D, 8-4)/
13. brown (5E-F, 8-4)/
14. light brown (6D, 6-4)/
15. grey-brown (6D-F, 3)/
16. dark-brown (6F, 8-3)/
17. dark-brown (7E-F, 8-4)/
18. red-brown (8D-E, 8-4)/

#33. \b{}Stipe\b0{} <presence> in youth/
1. a pad of tissue/
2. a fully formed stipe/
3. absent/

#34. <stipe presence adult basidiomata> in age/
1. becoming a pad of tissue/
2. becoming a fully formed stipe/
3. disappearing/
4. remaining unchanged/
5. remaining a pad of tissue (pseudostipe, \i{}sensu\i0{} Hesler and Smith)/

#35. <stipe> insertion in youth (primordial stage)/
1. central/
2. eccentric/
3. lateral/

#36. <stipe insertion> in age (pileus exhibiting full lateral extension)/
1. becoming central/
2. remaining central/
3. becoming eccentric/
4. remaining eccentric/
5. becoming lateral/
6. remaining lateral/
7. (disappearing)/

#37. <stipe> in profile/
1. equal/

2. clavate/
3. flexuous/
4. bulbous/

#38. <stipe> base/
1. swollen/
2. with velar remnants/
3. with attached rhizomorphs/
4. inserted/
5. radicated/
6. with basal tomentum/
7. equal/

#39. <stipe vestiture> surface/
1. glabrous/
2. glandular-dotted/
3. scabrous/
4. reticulate/
5. longitudinal-striate/
6. rugulose/
7. rugose/
8. caniculate/
9. pubescent/
10. minutley fibrillose/

#40. <stipe color>/
1. concolorous with pileus/
2. off white (1A1)/
3. vivid yellow to grey-yellow (3A-B, 8-3)/
4. yellow-grey to olive-grey (3B-F, 2)/
5. deep yellow to pale yellow (4A, 8-2)/
6. greyish yellow to light blond (4B-C, 8-2)/
7. olive-brown (4D-F, 8-3)/
8. brown-grey (4D-F, 2)/
9. golden-yellow (5B, 7)/
10. greyish orange (5B, 6-3)/
11. brown-yellow to brown-orange (5C, 8-3)/
12. yellow-brown to dark blond (5D, 8-4)/
13. brown (5E-F, 8-4)/
14. light brown (6D, 6-4)/
15. grey-brown (6D-F, 3)/
16. dark brown (6F, 8-3)/
17. dark brown (7E-F, 8-4)/
18. red-brown (8D-E, 8-4)/

#41. <stipe range> <short to long> in length/
mm/

#42. <basal tomentum> basal tometum/
1. present/
2. absent/

#43. <basal tomentum characteristics when present>/

#44. \b{}Basidiospores\b0{} <shape> in profile/
1. elliptic/
2. lentiform/
3. oblong/
4. cylindric/
5. bacciliform/
6. fusiform/
7. citriniform/
8. dacryoid/
9. ovoid/
10. pyriform/
11. amygdaliform/
12. amygdaliform with acute apex/
13. subcylindrical/
14. broadly elliptic/

#45. <spore shape> in frontal view/
1. elliptic/
2. lentiform/
3. oblong/
4. cylindric/
5. bacciliform/
6. fusiform/
7. citriniform/
8. dacryoid/
9. ovoid/
10. obovoid/
11. pyriform/
12. amygdaliform/
13. hexagonal/
14. subcylindrical/

#46. <spore> l x w range = /

#47. <basidiospore> Length average range /
1. 5.0-5.6 um/
2. 5.6-6.0 um/
3. 6.1-6.5 um/
4. 6.6-7.2 um/
5. 7.3-8.0 um/
6. 8.1-9.0 um/
7. 9.1-10.0 um/
8. 10.1-11.0 um/
9. 11.1-12.0/

#48. <spore mean length> L\sub{}x\nosupersub{} =/

#49. <spore mean width> W\sub{}x\nosupersub{} =/

#50. <spore L-W quotient> Q in profile =/
1. 1.01-1.05 um/
2. 1.06-1.15 um/
3. 1.16-1.30 um/
4. 1.31-1.60 um/
5. 1.61-2.0 um/
6. 2.1-3.0 um/
7. greater than 3.0/

#51. spore Q in profile exactly/

#52. <spore volume> V =/
um/

#53. <spore> Breadth range (B\sub{}R\nosupersub{})=/

#54. <spore mean breadth> mean breadth (B\sub{}x) \nosupersub{}=/

#55. <spore> Polar width range (P\sub{}WR\nosupersub{}) =/

#56. <spore mean polar width> Polar width mean (P\sub{}WX)\nosupersub{} =/

#57. <spore> Polar breadth range (P\sub{}BR\nosupersub{}) =/

#58. <spore mean polar breadth> Polar breadth mean (P\sub{}BX)\nosupersub{}=/

#59. apical germ pore /
1. distinct/
2. indistinct/

#60. <apical germ pore> and/
1. centric/
2. eccentric/

#61. <spore> wall thickness/
1. less than or equal to 0.5 um/
2. 0.6 to 1.0 um/
3. greater than or equal to 1.1 um/

#62. \b{}Basidia \b0{}originating in /
1. the trama/
2. the subhymenium/

#63. <basidia shape>/
1. equal/
2. clavate/
3. obclavate/
4. constricted sub-apically/

#64. <basidia shape> to/
1. equal/
2. clavate/
3. obclavate/
4. constricted sub-apically/
5. remaining unchanged/

#65. <basidia> L\sub{}x\nosupersub{} =/

#66. <basidia> W\sub{}x\nosupersub{} = /
um/

#67. <basidia> Length average range/
1. less than 11 um/
2. 11-13 um/
3. 14-16 um/
4. 17-19 um/
5. 20-22 um/
6. 23-25 um/
7. greater than 26 um/

#68. <basidia> l x w range = /

#69. <number of> sterigmata/

1. 4/
2. 2-4/
3. 2/

#70. \b{}Cheilocystidia\b0{} /
1. rare and scattered/
2. clustered in tufts/
3. very abundant/
4. absent/

#71. <cheilocystidia> originating in /
1. the hymenium/
2. the subhymenium/
3. the trama/

#72. <cheilocystidia shape> /
1. hyphoid/
2. globose/
3. pyriform/
4. clavate/
5. urtriform/
6. lageniform/
7. fusoid/
8. lanceolate/
9. tibiform/
10. lecythiform/
11. urtriform/
12. ventricose-rostrate/
13. capitulate/
14. filiform/
15. mucronate/
16. cylindrical/
17. sphaeropedunculate/
18. flexuose/

#73. <cheilocystidia shape> to/
1. hyphoid/
2. globose/
3. pyriform/
4. clavate/
5. urtriform/
6. lageniform/
7. fusoid/
8. lanceolate/

9. tibiiform/
10. lecythiform/
11. urticoid/
12. ventricose-rostrate/
13. capitulate/
14. filiform/
15. filiform and in fasicles/
16. cylcindrical/
17. sphaeropedunculate/
18. mucronate/
19. (same)/

#74. <cheilocystidia> L\sub{}x\nosupersub{} = /

#75. <cheilocystidia> W\sub{}x\nosupersub{} = /

#76. <cheilocystidia> l x w range = /

#77. <cheilocystidia> Length average range/
1. less than 12 um/
2. 13-14 um/
3. 15-17 um/
4. 18-20 um/
5. 21-23 um/
6. 24-26 um/
7. 27-28 um/
8. 29-31 um/
9. 32-43 um/
10. greater than 43 um/

#78. <cheilocystidia apex> /
1. glandular capitate/
2. dichotomous/
3. forked more than two times/
4. acute/
5. rounded/

#79. <cheilocystidia> wall pigments/
1. epiparietal granular/
2. epiparietal stippled/
3. absent/

#80. <cheilocystidia> hyphal wall pigment color/
1. golden-brown/

2. light-brown/
3. yellow/
4. dark-yellow/

#81. \b{}Pleurocystidia\b0{}/
1. rare and scattered/
2. scattered but frequent/
3. clustered in tufts/
4. very abundant/
5. embedded with an emergent neck/
6. absent/

#82. <pleurocystidia> originating in/
1. the hymenium/
2. the subhymenium/
3. the trama/

#83. <pleurocystidia shape>/
1. hyphoid/
2. globose/
3. pyriform/
4. clavate/
5. urtriform/
6. lageniform/
7. fusoid/
8. lanceolate/
9. tibiiform/
10. lecythiform/
11. urtriform/
12. venrticose-rostrate/
13. capitulate/
14. filiform/
15. mucronate/
16. cylindrical/
17. sphaeorpedunculate/
18. flexuose/

#84. <pleurocystidia shape> to/
1. hyphoid/
2. globose/
3. pyriform/
4. clavate/
5. urtiform/
6. lageniform/

7. fusoid/
8. lanceolate/
9. tibiiform/
10. lecythiform/
11. urtriform/
12. ventricose-rostrate/
13. capitulate/
14. filiform/
15. mucronate/
16. cylindrical/
17. sphaeropedunculate/
18. flexuose/
19. (same)/

#85. <pleurocystidia> L\sub{}x\nosupersub{} =/
um/

#86. <pleurocystidia> W\sub{}x\nosupersub{} =/

#87. <pleurocystdia> l x w range = /

#88. <pleurocystidia> Length average range/
1. less than 13 um/
2. 14-15 um/
3. 16-17 um/
4. 18-20 um/
5. 21-23 um/
6. 24-28 um/

#89. <pleurocystdia> apex/
1. glandular capitate/
2. dichotomous/
3. forked more than two times/
4. rounded/

#90. <pluerocystidia> wall pigments/
1. epiparietal granular/
2. epiparietal stippled/
3. absent/

#91. <pellis structure> \b{}Suprapellis\b0{} a/
1. lattice/
2. cutis/
3. trichoderm/

4. ixocutis/
5. ixotrichodermium/
6. enterocutis/
7. ixoenterocutis/

#92. <pileus suprapellis> hyphal diam. range =/

#93. <pileus suprapellis> hyphal diam. mean/
um/

#94. <pileus suprapellis> wall thickness/
1. less than or equal to 0.5um/
2. 0.6 to 1.0 um/
3. greater than or equal to 1.1 um/

#95. <pileus suprapellis> clamp connections/
1. present/
2. absent/

#96. <pileus suprapellicle> hyphal external pigments/
1. epiparietal granular/
2. epiparietal stippled/
3. absent/

#97. <pileus suprapellicle hyphae pigment color>/
1. golden-brown/
2. light-brown/
3. yellow/
4. dark-yellow/

#98. <pileus suprapellis> elements that extrude from pellicle hyphae/
1. filiform/
2. swollen/
3. irregularly branched/
4. absent/

#99. <pileus suprapellis> to/
1. filiform/
2. swollen/
3. irregularly branched/
4. remaining unchanged/

#100. <pileus extruding terminal elements pellis hyphae> hyphal diam. range
= <small to large>/

#101. <pileus extruding terminal elements> mean diam. =/
um/

#102. <pileus suprapellis terminal elements> wall thickness/
1. less than or equal to 0.5 um/
2. 0.6 um to 1.0 um/
3. greater than or equal to 1.1 um/

#103. <pileus suprapellicle terminal elements hyphae> external pigments/
1. epiparietal granular/
2. epiparietal stippled/
3. absent/

#104. <pileus suprapellicle terminal elements hyphal pigment color>/
1. golden-brown/
2. light-brown/
3. yellow/
4. dark-brown/

#105. <pileus pellicle structure> \b{}Mediopellis\b0{} /
1. parenchymatic/
2. cellular/
3. ixocellular-parenchymatic/
4. interwoven/
5. ixointerwoven/
6. absent/

#106. <pileus mediopellis> hyphal diam. = <range small to large>/
um/

#107. <pileus mediopellis> hyphal diam. mean =/
um/

#108. <pileus mediopellis> clamp connections/
1. present/
2. absent/

#109. <pileus mediopellis> hyphal wall pigments/
1. epiparietal granular/
2. epiparietal stippled/
3. absent/

#110. <pileus mediopellis hyphal pigment color>/

1. golden-brown/
2. light-brown/
3. yellow/
4. dark-yellow/

#111. <pileus pellicle> \b{}Subpellis\b0{} /
1. parenchymatic/
2. radially interwoven/
3. tangentially interwoven/
4. absent/

#112. <pileus subpellis> hyphal diam. range =/
um/

#113. <pileus subpellis> hyphal diam. mean = /
um/

#114. <pileus subpellis> clamp connections/
1. present/
2. absent/

#115. <subpellicle hypahe> external pigments/
1. epiparietal granular/
2. epiparietal stippled/
3. absent/

#116. <subpellicle hyphae pigment color>/
1. golden-brwon/
2. light-brown/
3. yellow/
4. dark-yellow/

#117. \b{}Mucus\b0{} depth <depth> at disc/
um/

#118. \b{}Pileal trama\b0{} <organization>/
1. interwoven/
2. interwoven with swollen elements/
3. bi-stratous/
4. ixointerwoven/
5. parenchymatic/
6. parenchymatic with interwoven elements/
7. parallel/

#119. <pileal trama> hyphal wall thickness/
1. less than or equal to 0.5 um/
2. 0.6 um to 1.0 um/
3. greater than or equal to 1.1 um/

#120. <pileal trama> hyphal diam. mean =/
um/

#121. <pilela trama> hyphal diam. range/

#122. <pileal trama> Diam. average range/
1. less than 2 um/
2. 3-4 um/
3. 5-6 um/
4. 7-8 um/
5. 9-10 um/
6. 11-12 um/

#123. <pileal trama> hyphal inflation/
1. present/
2. prevalent/
3. scarce/
4. absent/

#124. <pileal trama> clamp connections/
1. present/
2. absent/

#125. <pileal trama> wall pigments/
1. epiparietal granular/
2. epiparietal stippled/
3. absent/

#126. <pileal trama wall pigments color>/
1. golden-brown/
2. light-brown/
3. yellow/
4. dark-yellow/

#127. \b{}Lamellar\b0{} trama <organization>/
1. interwoven/
2. parallel/
3. subparallel/
4. parenchymatic/

5. cellular/

#128. <lamellar trama organization> to/
1. interwoven/
2. parallel/
3. subparallel/
4. parenchymatic/
5. cellular/

#129. <lamellae trama> wall thickness/
1. less than or equal to 0.5 um/
2. greater than or equal to 0.6 um/

#130. <lamellae trama> hyphal diamter range =/

#131. <lamellae trama> hyphal diam. mean =/
um/

#132. <lamellar trama> Diam. average range/
1. less than 2 um/
2. 3-4 um/
3. 5-6 um/
4. 7-8 um/
5. 9-10 um/
6. 10-11 um/
7. 12-13 um/
8. greater than 13 um/

#133. <lamellae trama> wall pigmentation/
1. epiparietal granular/
2. epiparietal stippled/
3. absent/

#134. <lamellae trama wall pigment color>/
1. golden-brown/
2. light-brown/
3. yellow/
4. dark-yellow/

#135. \b{}interlamellal\b0{} <hyphae> organization/
1. cellular/
2. parenchymatic/
3. similiar to pileal trama/

#136. <interlamellal trama> hyphal diam. range = /

#137. <interlamellal> Diam. average range/
1. less than or equal to 9 um/
2. 10-12 um/
3. 13-15 um/
4. greater than 16 um/

#138. <interlamellal trama> hyphal diam. mean =/
um/

#139. \b{}subhymenium\b0{} <arrangement>/
1. parenchymatic/
2. cellular/
3. interwoven/
4. ixo/
5. indistinct from tama proper/

#140. <subhymenium> hyphal wall pigments/
1. epiparietal granular/
2. epiparietal stippled/
3. absent/

#141. <subhymenium hyphal wall pigment> color/
1. golden-brown/
2. light-brown/
3. yellow/
4. dark-yellow/

#142. <subhymenium> cell diam. range =/
um/

#143. <subhymenium> cell diam. mean =/
um/

#144. \b{}Stipe\b0{} pellicle hyphae <arrangement>/
1. parallel/
2. subparallel/
3. divergent/
4. convergent/
5. cellular/

#145. <stipe> hyphae medullary zone <composition>/
1. parallel/

2. subparallel/
3. divergent/
4. convergent/
5. cellular/
6. indistinct from pellis/

#146. <stipe> Trama average range diam./
1. less than 2 um/
2. 2.1-4 um/
3. 4.1-5 um/
4. 5.1-6 um/
5. 6.1-7 um/
6. 7.1-8 um/
7. 8.1-9 um/
8. 9.1-10 um/
9. 10.1-11 um/
10. 11.1-12 um/
11. 12.1-13 um/
12. 13.1-14 um/
13. 15.1-16 um/
14. greater than 16 um/

#147. <stipe> hyphal wall thickness/
1. less than or equal to 0.5 um/
2. 0.6 um to 1.0 um/
3. greater than or equal to 1.1 um/

#148. <stipe> Pellis average range diam./
1. less than 2 um/
2. 2.5-3 um/
3. 4-5 um/
4. greater than 5 um/

#149. <stipe> hyphal wall pigments/
1. epiparietal granular/
2. epiparietal stippled/
3. absent/

#150. <stipe hyphal wall pigment color>/
1. golden-brown/
2. light-brown/
3. yellow/
4. dark-yellow/

#151. \b{}Caulocystidia\b0{}/
1. rare and scattered/
2. clustered in tufts/
3. very abundant/
4. absent/

#152. <caulocystidia origination> /
1. stipe pellis/
2. stipe trama/

#153. <caulocystidia> shape/
1. hyphoid/
2. globose/
3. pyriform/
4. clavate/
5. utriform/
6. capitate/
7. lageniform/
8. fusoid/
9. lanceolate/
10. tibiiform/
11. lecthyform/
12. urticoid/
13. filiform/
14. filiform and in fasicles/
15. ventricose-rostrate/
16. contorted/

#154. <caulocystidia> L\sub{}x\nosupersub{} = /
um/

#155. <caulocystidia> W\sub{}x\nosupersub{} = /
um/

#156. <caulocystidia> l x w range =/

#157. <caulocystidia> apex/
1. glandular capitate/
2. dichotomous/
3. forked more than two times/
4. acute/

#158. <caulocystidia> hyphal wall pigments/
1. epiparietal granular/

2. spiparietal stippled/
3. absent/

#159. <caulocystidia hypahe wall pigment color>/
1. golden-brown/
2. light-brown/
3. yellow/
4. dark-yellow/

#160. \b{}Pileocystidia\b0{} <present or not>/
1. rare and scattered/
2. clustered in tufts/
3. very abundant/
4. absent/
5. scattered/

#161. <pileocystidia shape>/
1. hyphoid/
2. globose/
3. pyriform/
4. clavate/
5. utriform/
6. lageniform/
7. fusoid/
8. lanceolate/
9. tibiiform/
10. lecythiform/
11. urttriform/
12. ventricose-rostrate/
13. capitulate/
14. filiform/
15. mucronate/
16. cylindrical/
17. sphaeropedunculate/
18. flexuose/
19. absent/

#162. <pileocystidia> L\sub{}x\nosupersub{} =/
um/

#163. <pileocystidia> W\sub{}x \nosupersub{}= /
um/

#164. <pileocystidia> l x w range = /

#165. <pileocystidia> apex/
1. glandular capitate/
2. dichotomous/
3. forked more than two times/
4. acute/
5. rounded/

#166. <pileocystidia> wall pigments /
1. epiparietal granular/
2. epiparietal stippled/
3. absent/

#167. <pileocystidia hyphae wall pigment color>/
1. golden-brown/
2. light-brown/
3. yellow/
4. dark-yellow/

#168. <Comments>/

APPENDIX C: CULTURE MEDIA

1. Malt Extract Agar (MEA)

Bacto-Agar (Difco)	20 g
Malt Extract (Difco)	12.5g
Distilled Water	1L

2. Mealt Extract Broth (MEB)

Malt Extract (Difco)	12.5g
Distilled Water	1L

APPENDIX D: DNA EXTRACTION

1. Total DNA Extraction Solutions

Extraction Buffer	600 µl (Gentra Systems. Inc., Minneapolis, MN)
Protien Precipitation Solution	200 µl (Gentra Systems. Inc., Minneapolis, MN)
Liquid Nitrogen	500 ml
Polyvinylpolyrrolidone (PVPP)	.5 g
95% Ehanol	1L
70% Ethanol	1L
100% Isopropanol	1L
Double Distilled Water	50 ml

APPENDIX E: PCR AMPLIFICATION PRIMERS

1. PCR Primers (BioVentures, Inc., Murfreesburo, TN)

a) 8.6 GAGCCTGT

b) 8.6 GACGTAGG

c) 8.6 GATCGCAG

d) 8.6 CTAACGCC

e) 8.6 GTTACGCC

f) 8.6 GTATCGCC

g) 8.7 AATGCAGC

h) 8.7 CGTGGTGG

i) 8.7 CCTGCTGG

APPENDIX F: POLYACRYLAMIDE ELECTROPHORESIS SOLUTIONS

1. 10X TBE Buffer (Trigiano et al., 1998)

Tris Base	121.1 g
Boric Acid	51.4 g
Sodium EDTA	3.7g pH 8.0
Double-Distilled Water	1L

2. Anticracking Solution (Trigiano et al., 1998)

Glacial Acetic Acid	100ml
95% Ethanol	370 ml
Double Distilled Water	520 ml
Glycerol	10 ml

3. DNA Loading Buffer (Trigiano et al., 1998)

Urea	12 g

xylene stock solution*2 ml (*4mg xylene cyanol/ml water)

4) Silver Stain and Developer Solution (Trigiano et al., 1998)

silver stain:

ACS certified $AgNO_3$	.15 g
Double Distilled Water	150 ml
16% Formaldehyde	750 µl

developer solution:

ACS certified $NaCO_3$	4.5 g
Double Distilled Water	150 ml

Sodium Thiosulfate Solution*	75 µl (*0.2g/ml)
16% Formaldehyde	600 µl

5) Fixing Solution

Acetic Acid	75 ml
Double Distilled Water	1L

6) 10% Polyacrylamide Stock (Trigiano et al., 1998)

acrylamide	19.6 g (BioRad, Hercules, CA)
Piperazine Diacrylamide (PDA)	0.4 g
Urea	20 g
Double Distilled Water	430 ml
10X TBE Buffer	20 ml
Glycerol	10 ml

APPENDIX G: SELF-CROSS DIAGRAMS USED IN MATING TYPE DETERMINATION

A. Group I: *M. alpiniae*

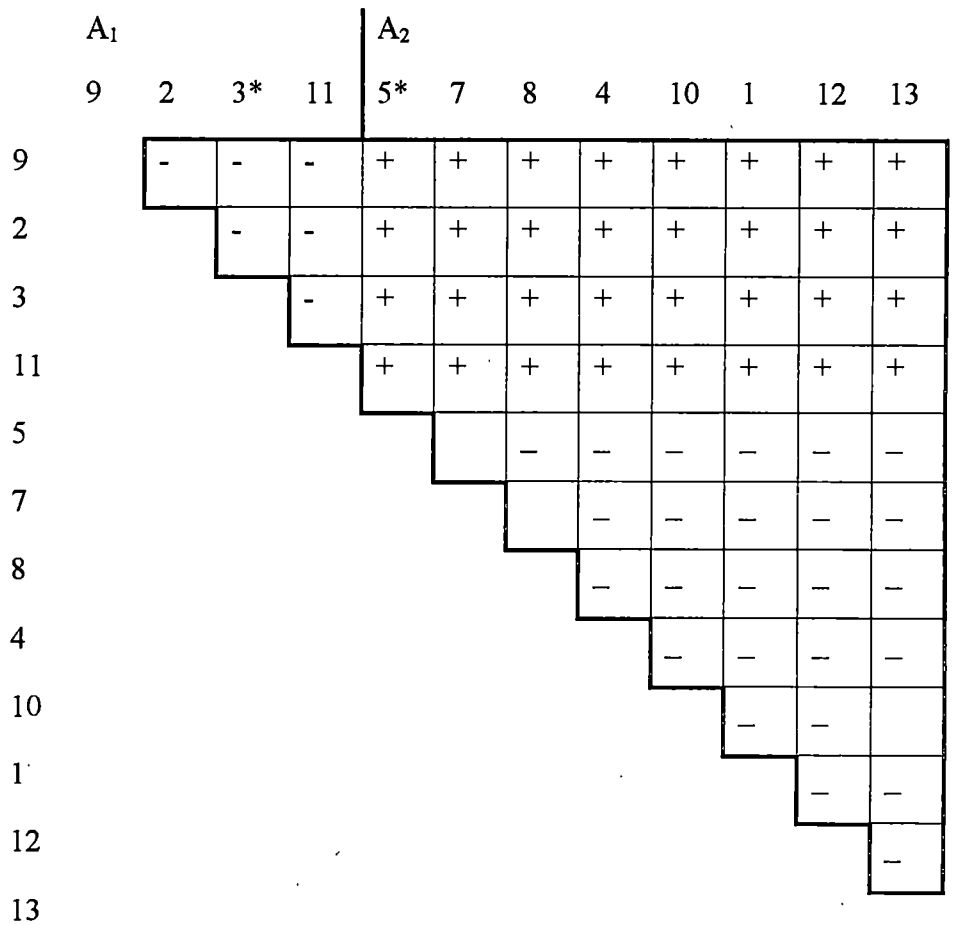


Figure 4. Self-cross analysis of single-basidiospore isolates derived from *M. alpiniae* 3487 (TENN 48861). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table. (Modified from Petersen, 1992a:59)

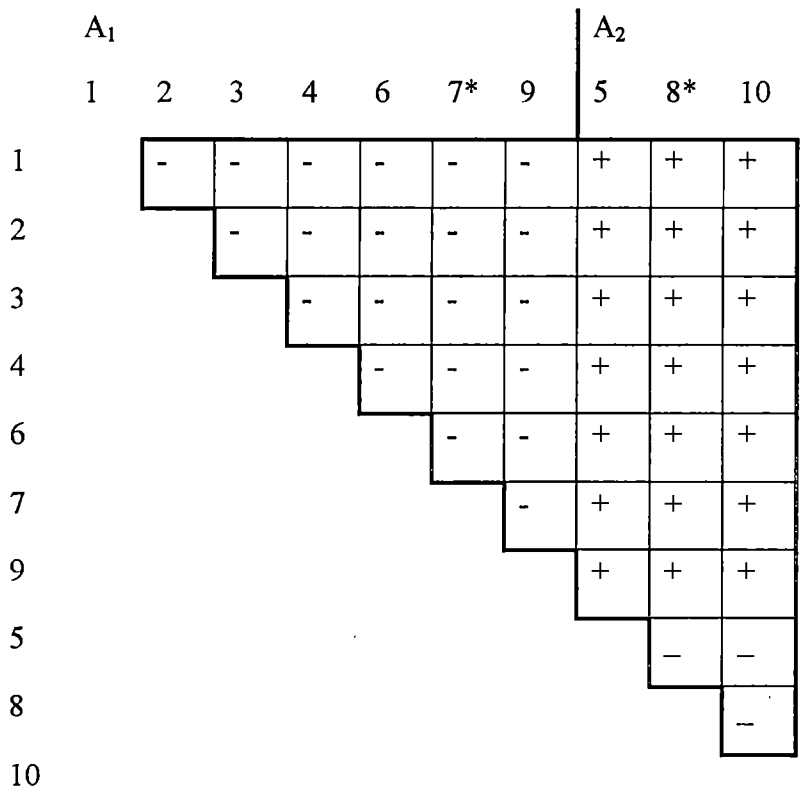


Figure 5. Self-cross analysis of single-basidiospore isolates derived from *M. alpiniae* 2443 (TENN 48727). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. . Single-basidiospore isolates and assigned mating types are indicated along top of table. (Modified from Petersen, 1992a:60).

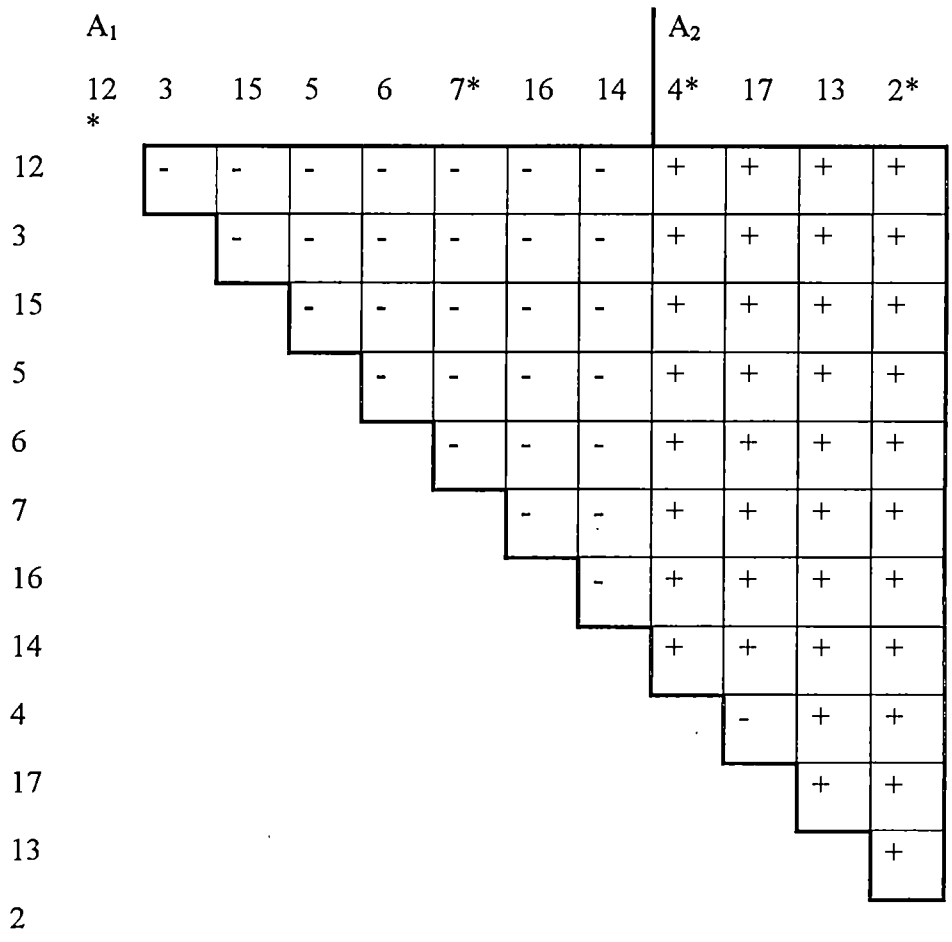


Figure 6. Self-cross analysis of single-basidiospore isolates derived from *M. alpiniae* 3822et (TENN 58561). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

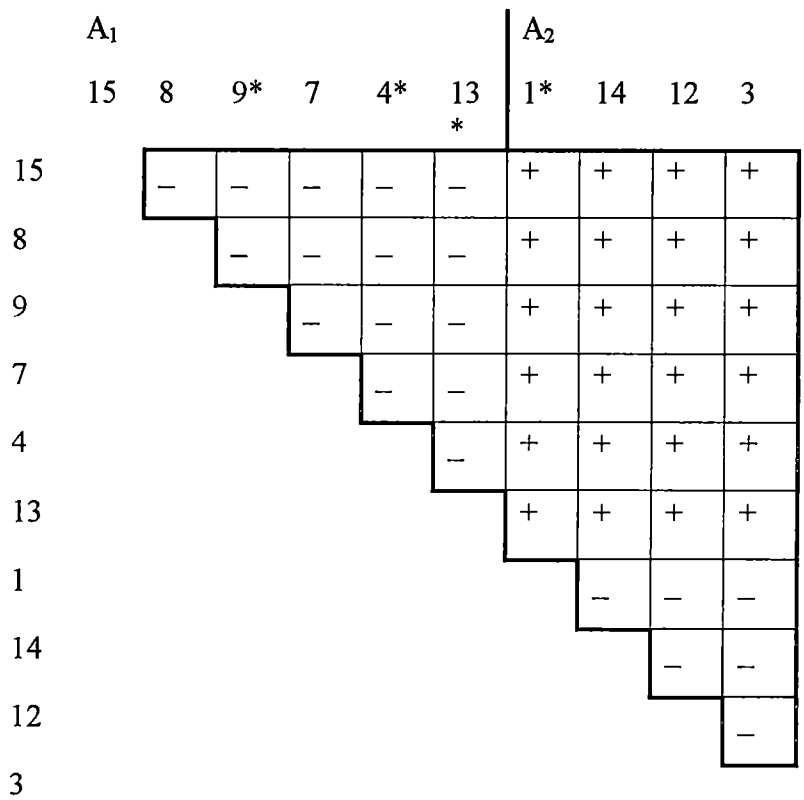


Figure 7. Self-cross analysis of single-basidiospore isolates derived from *M. alpiniae* 4862 (TENN 51161). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

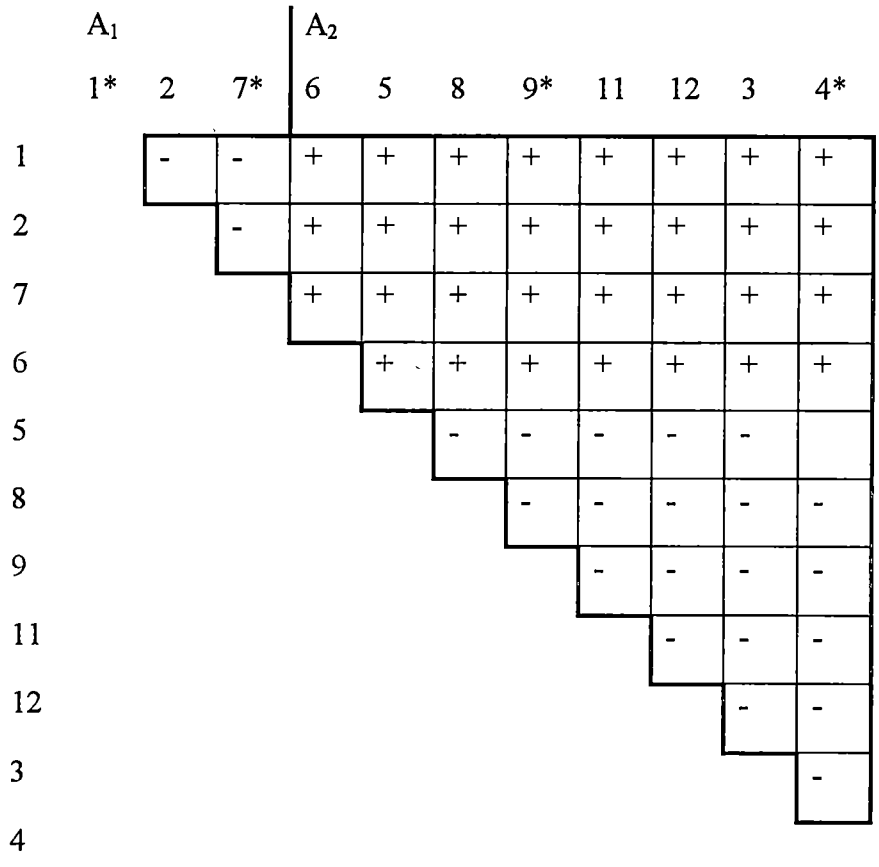


Figure 8. Self-cross analysis of single-basidiospore isolates derived from *M. alpiniae* 9323 (TENN 58549). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

B. *M. defraudatus*

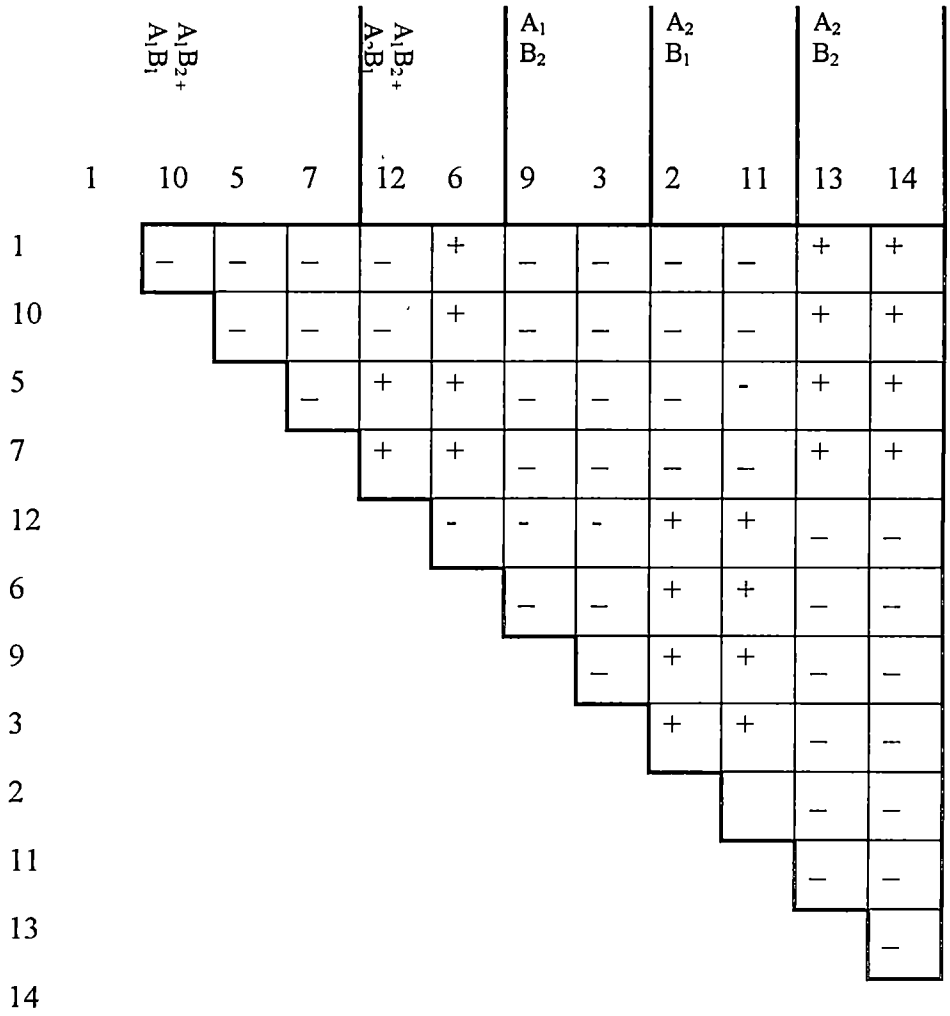


Figure 9. Self-cross analysis of single-basidiospore isolates derived *from M. defraudatus* 8594 (TENN 58548). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

C. *M. horizontalis* complex

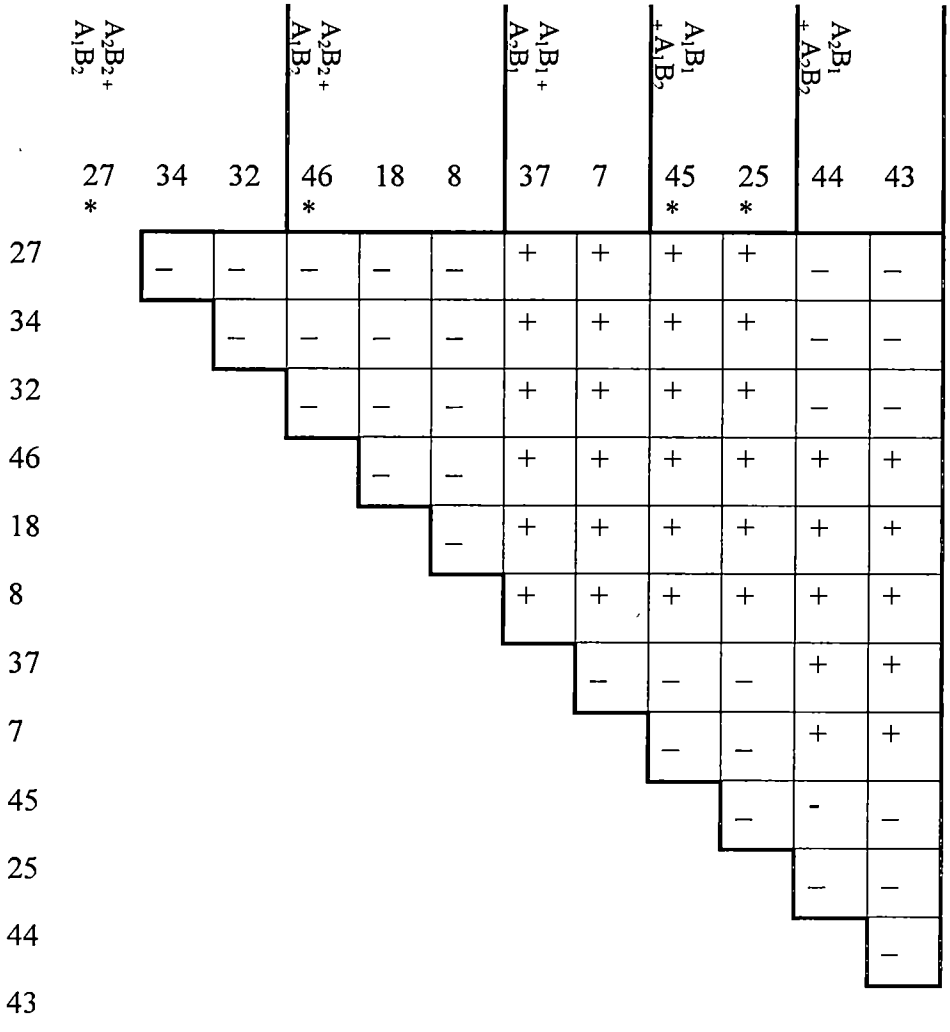


Figure 10. Self-cross analysis of single-basidiospore isolates derived from *M. horizontalis* GRW34 (TENN 58558). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

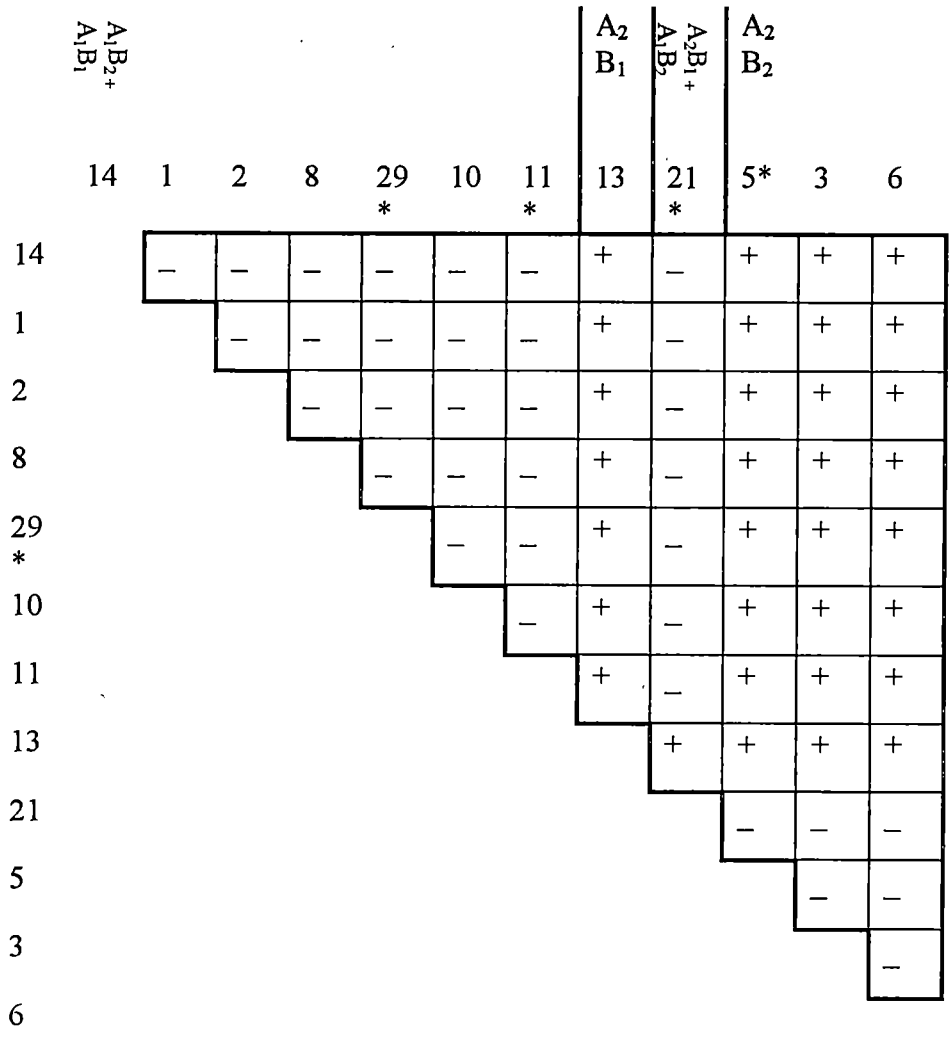


Figure 11. Self-cross analysis of single-basidiospore isolates derived from *M. horizontalis* 7319 (TENN 54933). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

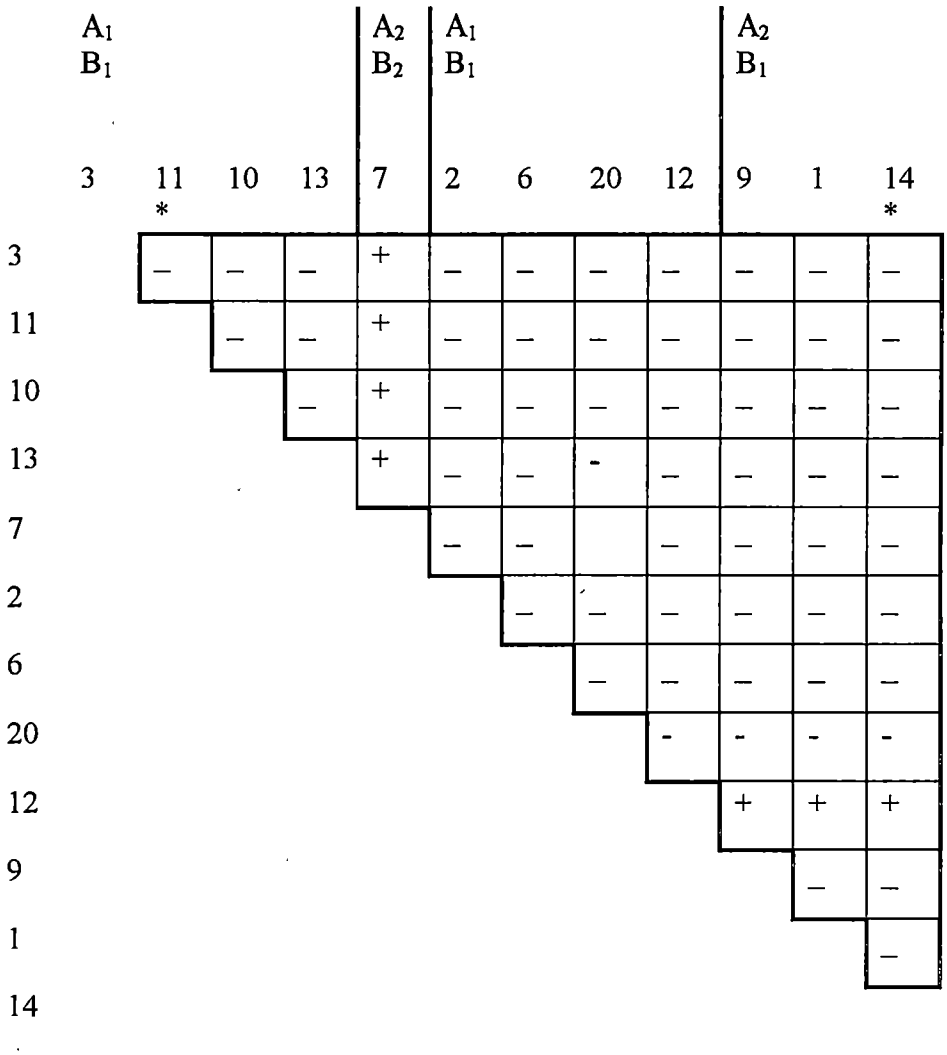


Figure 12. Self-cross analysis of single-basidiospore isolates derived from *M. horizontalis* PBM 772 (TENN 58550). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

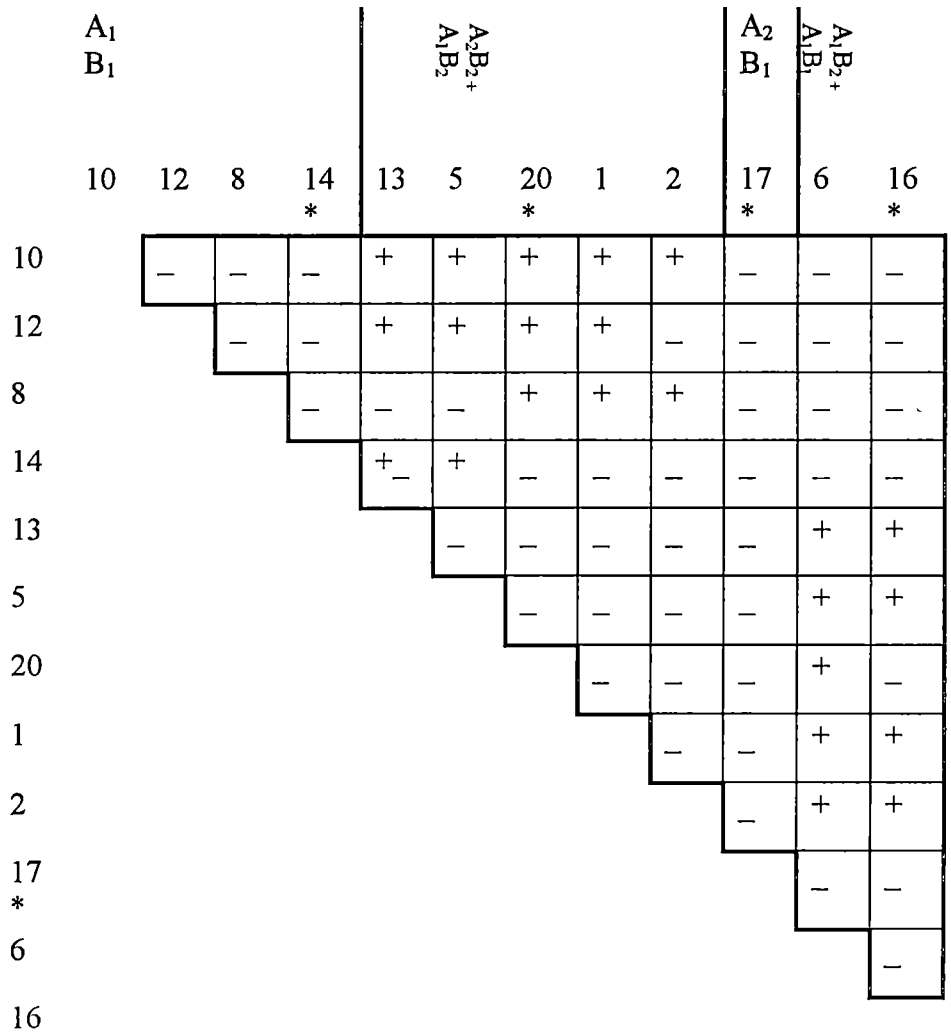


Figure 13. Self-cross analysis of single-basidiospore isolates derived from *M. horizontalis* 9037 (TENN 55724). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

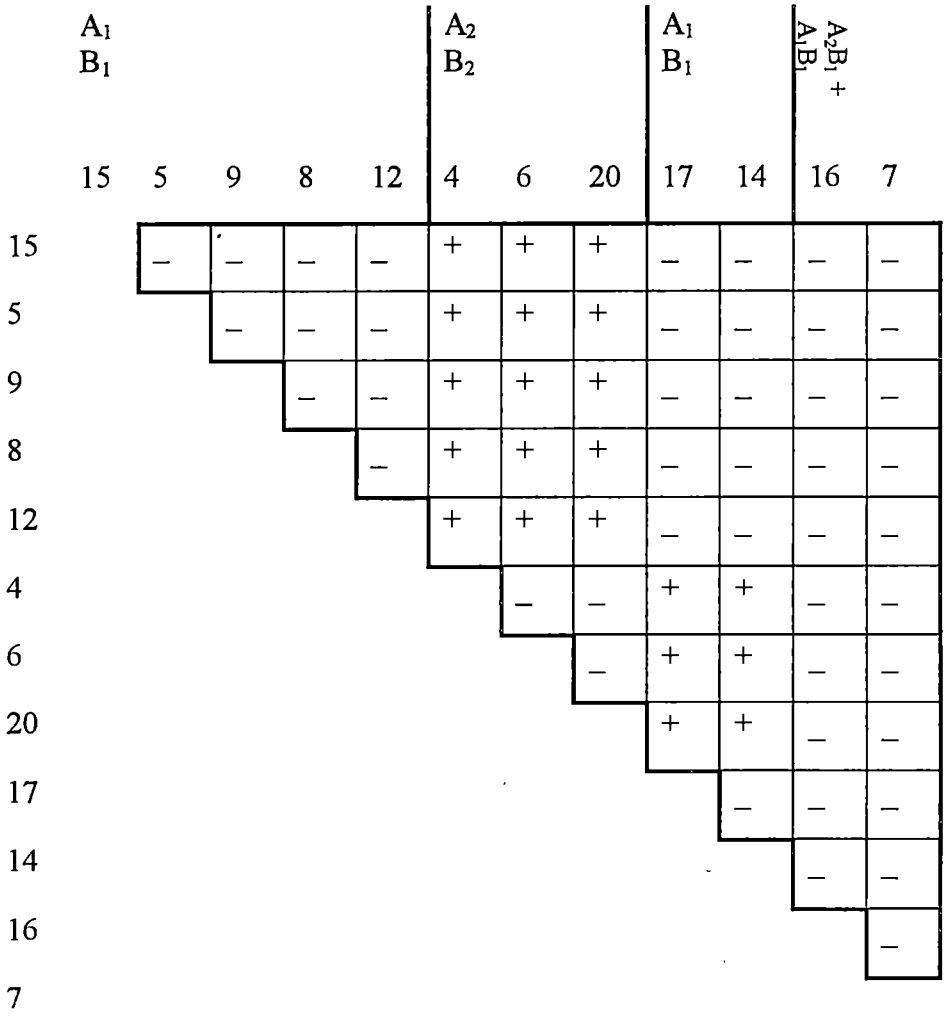


Figure 14. Self-cross analysis of single-basidiospore isolates derived from *M. horizontalis* 6963 (TENN 56288). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

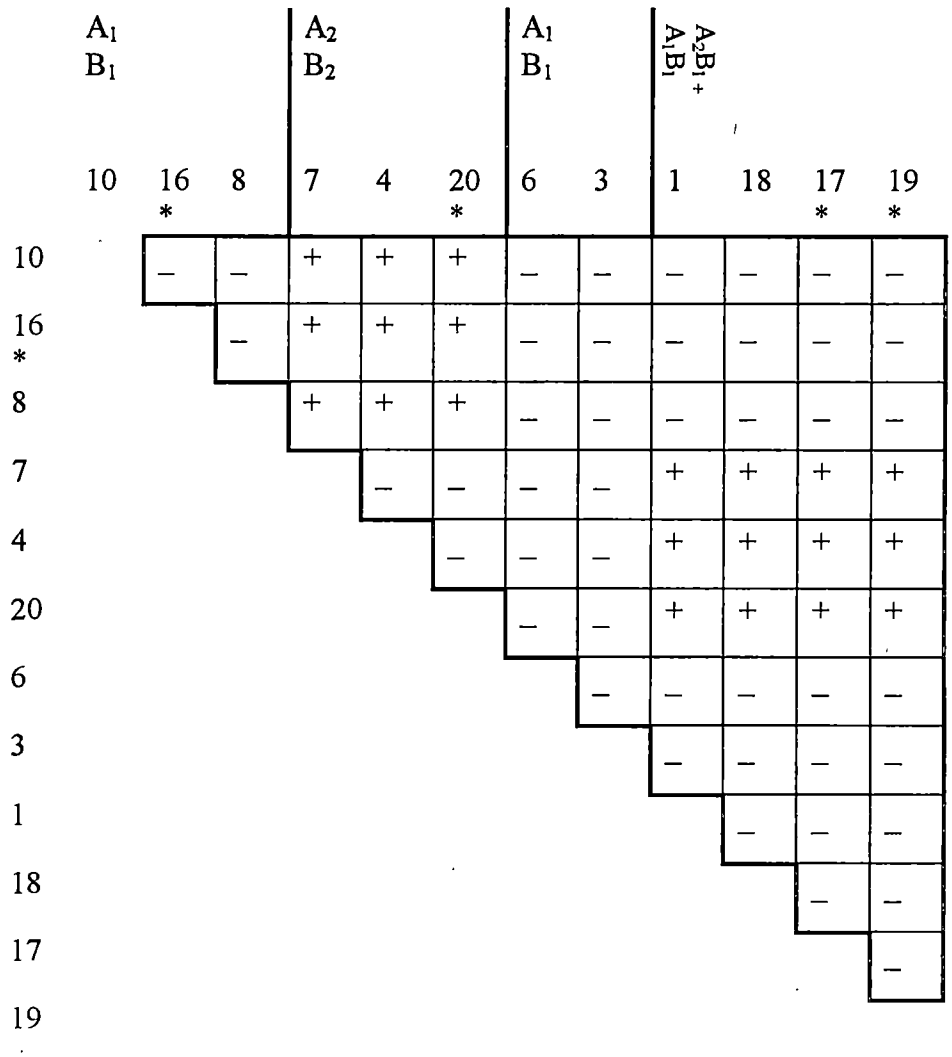


Figure 15. Self-cross analysis of single-basidiospore isolates derived from 6964 (TENN 56287). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

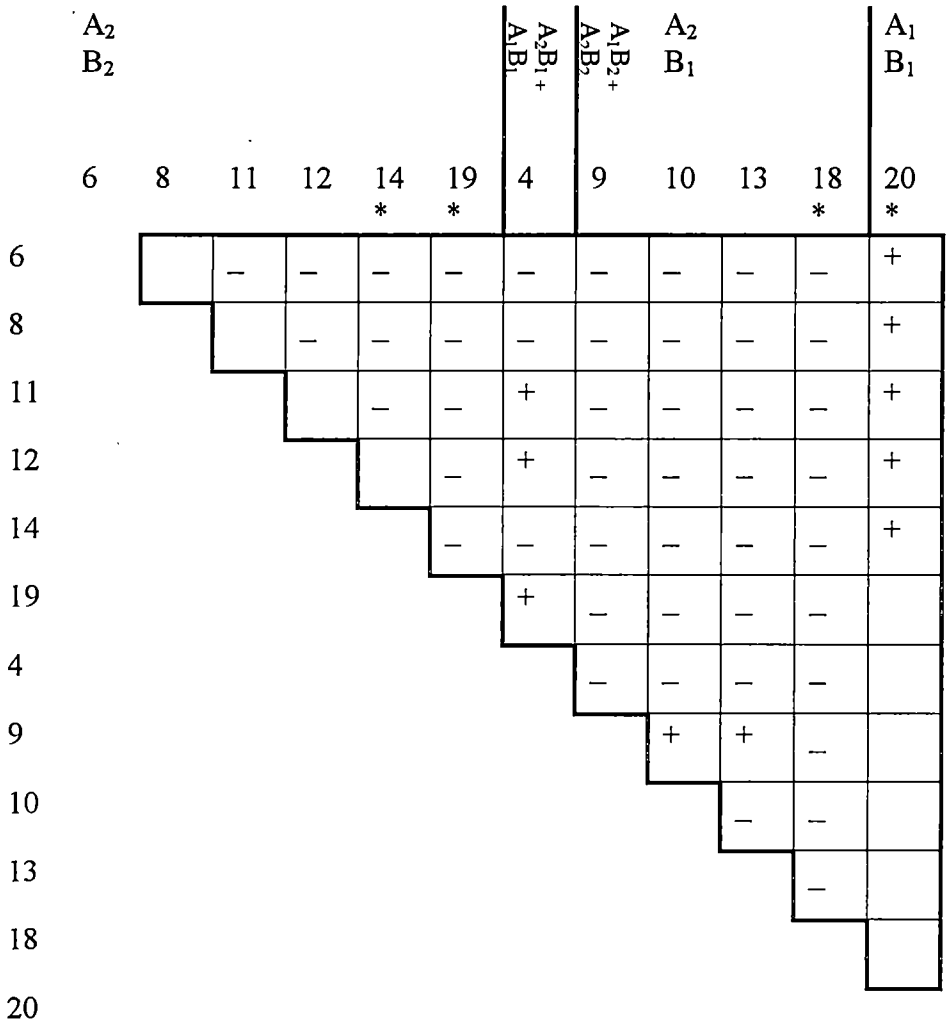


Figure 16. Self-cross analysis of single-basidiospore isolates derived from *M. horizontalis* 3862 (TENN 56290). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

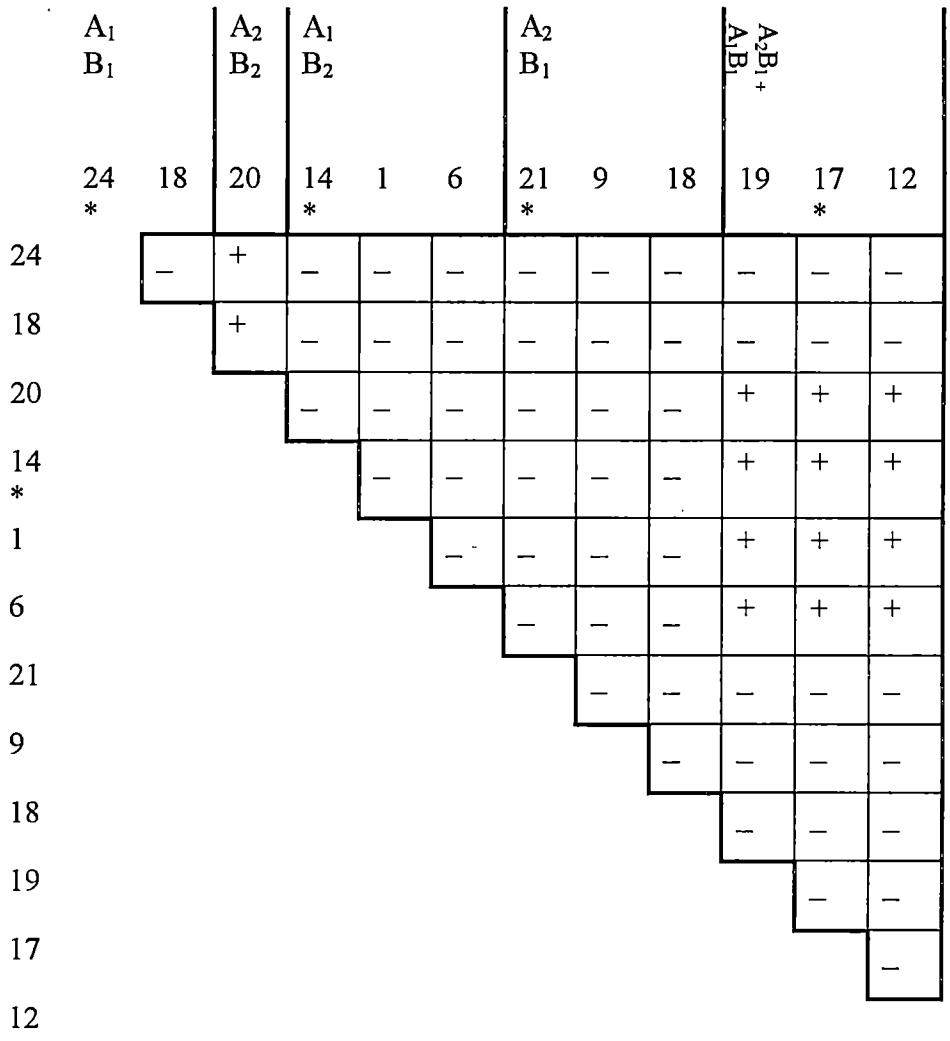


Figure 17. Self-cross analysis of single-basidiospore isolates derived from *M. horizontalis* 3583 (TENN 50137). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

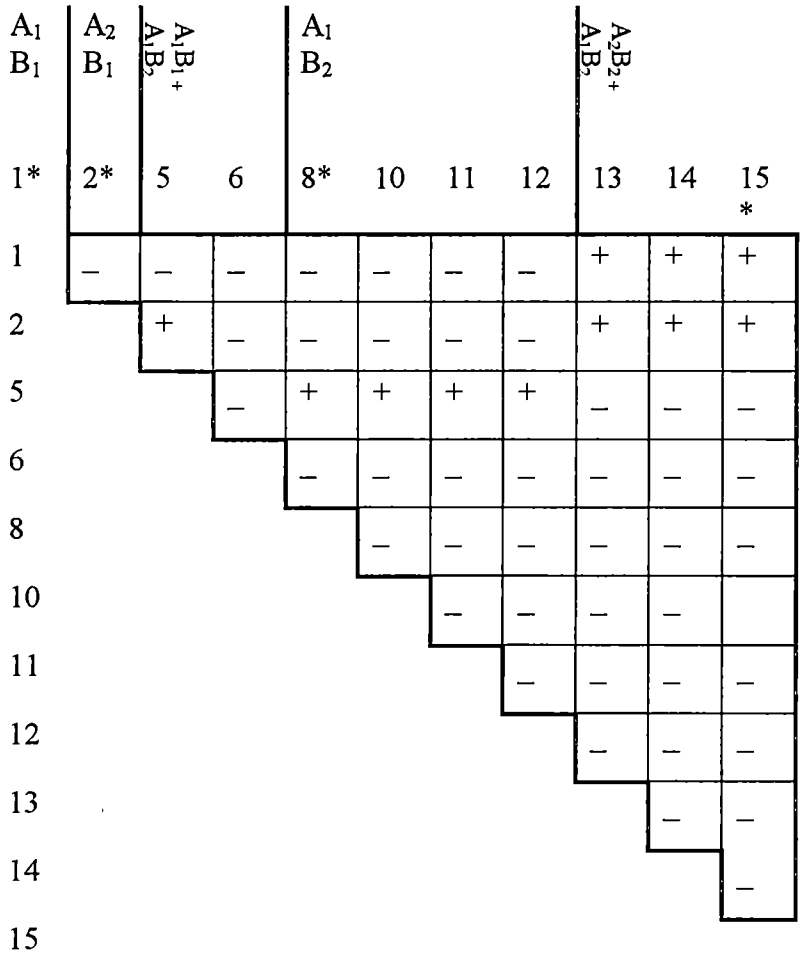


Figure 18. Self-cross analysis of single-basidiospore isolates derived from *M. horizontalis* 8614 (TENN 54953). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

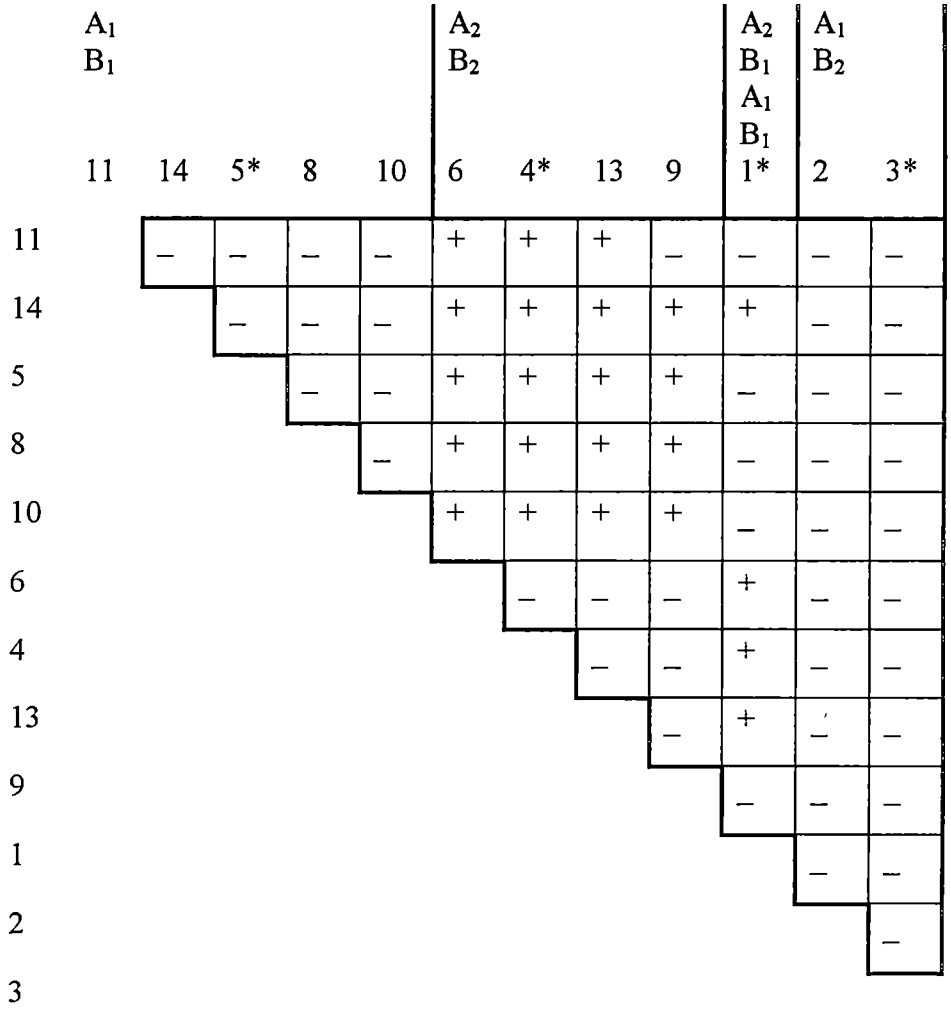


Figure 19. Self-cross analysis of single-basidiospore isolates derived from *M. horizontalis* 8650 (TENN 55372). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

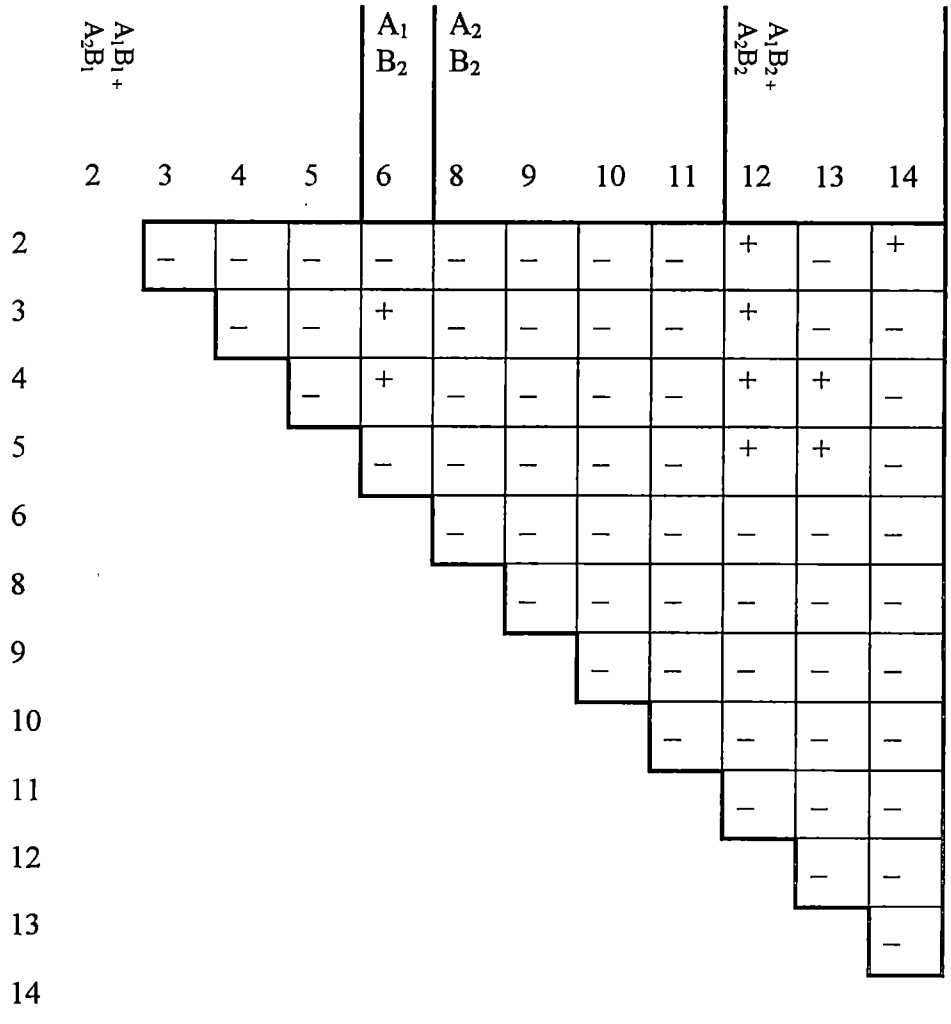


Figure 20. Self-cross analysis of single-basidiospore isolates derived from *M. horizontalis* 8651 (TENN 55373). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

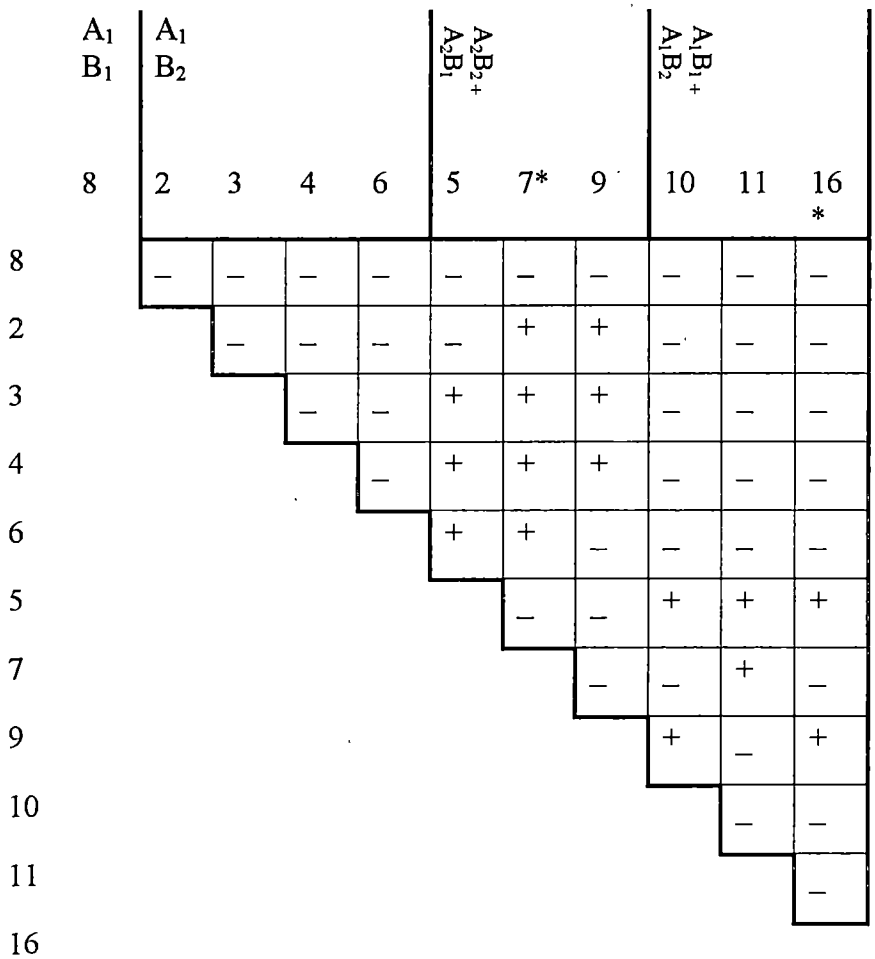


Figure 21. Self-cross analysis of single-basidiospore isolates derived from *M. horizontalis* 8656 (TENN 55378). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

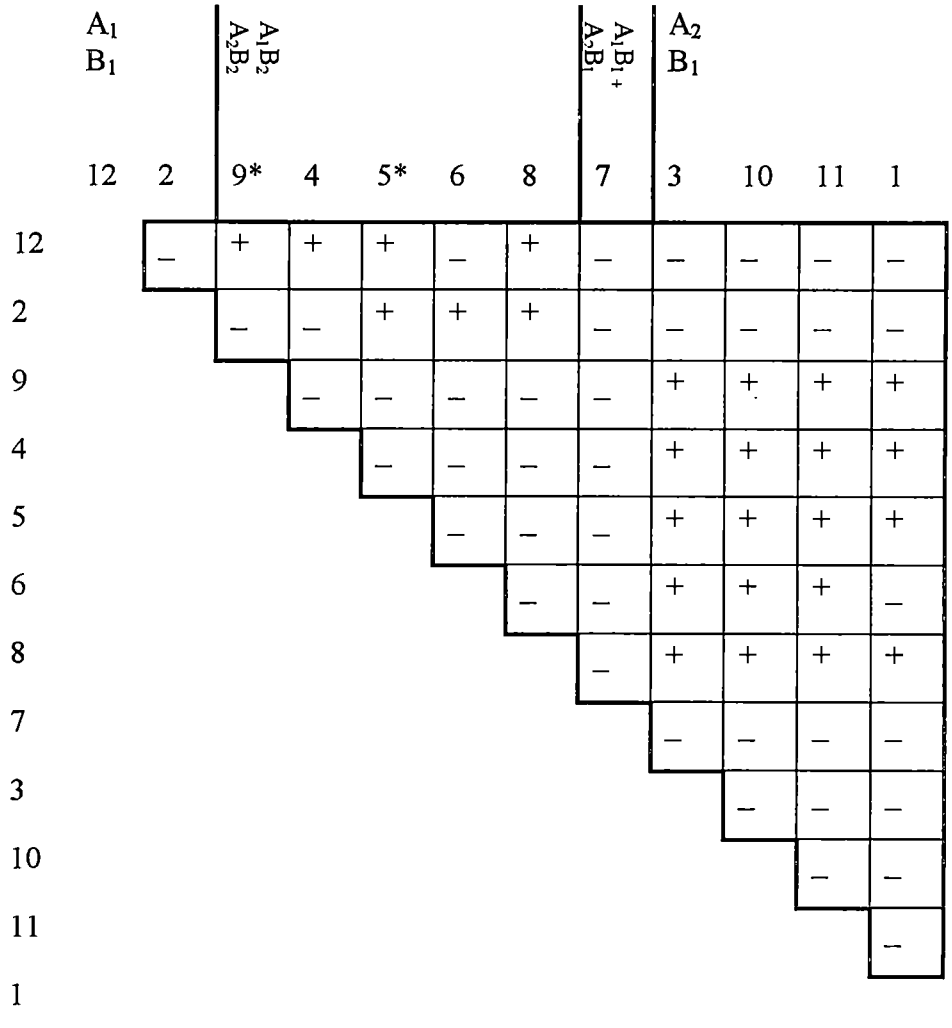


Figure 22. Self-cross analysis of single-basidiospore isolates derived from *M. horizontalis* 8657 (TENN 55379). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

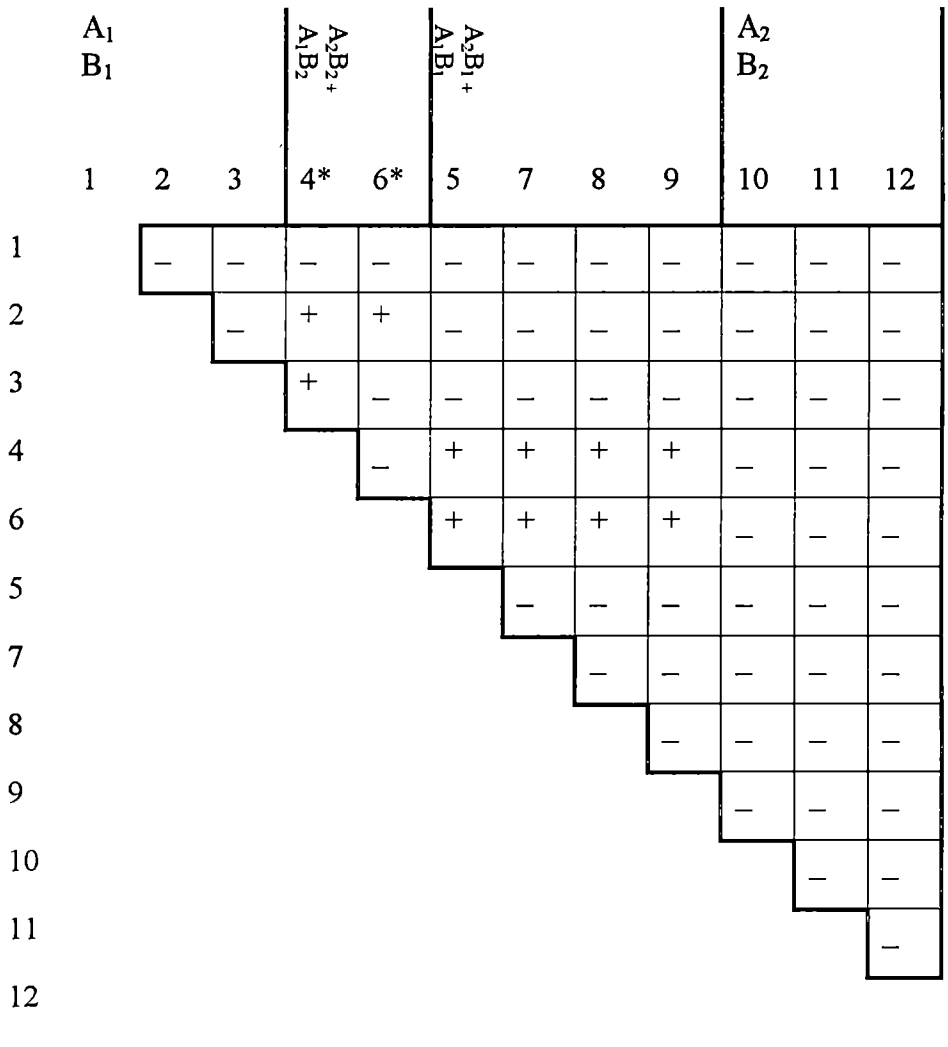


Figure 23. Self-cross analysis of single-basidiospore isolates derived from *M. horizontalis* 8660 (TENN 55381). + = compatible pairing with clamp connection formation; - = incompatible pairing; * = tester strain. Single-basidiospore isolates and assigned mating types are indicated along top of table.

APPENDIX H: RESULTS OF COMPATIBILITY EXPERIMENTS

A. Complete intercollection compatibility data

6963

3862	14	16	17	20
14	$_{+}+^{+}$	$_{-}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$
18	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$
19	$_{+}+^{+}$	$_{+}+^{+}$	$_{-}+^{+}$	$_{+}+^{-}$
20	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$

6964

3862	16	17	19	20
14	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$
18	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{-}$	$_{+}+^{+}$
19	$_{-}+^{+}$	$_{-}+^{-}$	$_{+}+^{+}$	$_{+}+^{+}$
20	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$

9037

3862	14	16	17	20
14	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{-}$
18	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$	$_{-}+^{+}$
19	$_{+}+^{+}$	$_{-}+^{+}$	$_{+}+^{-}$	$_{+}+^{+}$
20	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$

8560

3862	5	7	20	21
14	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$
18	$_{-}+^{+}$	$_{+}+^{-}$	$_{+}+^{+}$	$_{+}+^{+}$
19	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$	$_{+}+^{+}$
20	$_{-}+^{+}$	$_{+}+^{-}$	$_{+}+^{+}$	$_{+}+^{+}$

Intercollection pairings between single-basidiospore isolates of collections of *M. alpiniae*, *M. defraudatus*, and *M. horizontalis* as reported by TENN field book number. $_{+}+^{+}$ indicates compatible pairing with reciprocal conjugate nuclear divisions, $_{-}+^{-}$ indicates compatible pairing without reciprocal conjugate nuclear divisions, $_{-}+^{+}/_{+}+^{-}$ indicates compatible pairing with nuclear migration in the direction of the + symbol, - indicates incompatible pairing. Figures listed chronologically.

Appendix H (continued).

8561

		15	20	21	27
3862	14	+++	+++	+++	+++
	18	+++	+++	+++	+++
	19	+++	+++	+++	+++
	20	+++	+++	+++	+++

7319

		5	11	21	29
3862	14	+++	+++	+++	+++
	18	+++	+++	+++	+++
	19	+++	+++	+++	+++
	20	+++	+++	+++	+++

5734

		5	6	11	
3862	14	+++	+++	+++	
	18	+++	+++	+++	
	19	+++	+++	+++	
	20	+++	+++	+++	

grw34

		25	27	45	46
3862	14	+++	+++	+++	+++
	18	+++	+++	+++	+++
	19	+++	+++	+++	+++
	20	+++	+++	+++	+++

grw 34

		25	27	45	46
3862	14	+++	+++	+++	+++
	18	+++	+++	+++	+++
	19	+++	+++	+++	+++
	20	+++	+++	+++	+++

3583

		14	17	21	24
3862	14	+++	+++	+++	+++
	18	+++	+++	+++	+++
	19	+++	+++	+++	+++
	20	+++	+++	+++	+++

8614

		1	2	8	15
3862	14	+++	+++	+++	+++
	18	+++	+++	+++	+++
	19	+++	+++	+++	+++
	20	+++	+++	+++	+++

8652

		8	9	13	17
3862	14	+++ f			+++ f
	18		+++	+++	
	19		+++	+++	
	20	+++			+++

Appendix H (continued).

8653

		1	5	7	11
3862	14	+++	+++	+++	+++
	18	+++	+++	+++	+++
	19	+++	+++	+++	+++
	20	+++	+++	+++	+++

8656

		16	7		
3862	14	+++	+++		
	18	+++	+++		
	19	+++	+++		
	20	+++	+++		

9018

		7	10	11	18
3862	14	+++	+++	+++	+++
	18	+++	+++	+++	+++
	19	+++	+++	+++	+++
	20	+++	+++	+++	+++

8657

		9	5		
3862	14	+++	+++		
	18	+++	+++		
	19	+++	+++		
	20	+++	+++		

8661

		11	5		
3862	14	+++	+++		
	18	+++	+++		
	19	+++	+++		
	20	+++	+++		

3488

		2	7	11	18
3862	14	–			–
	18		–	–	
	19		–	–	
	20	–			–

9305

		8	10	16	17
3862	14	–			–
	18		–	–	
	19		–	–	
	20	–			–

9315

		3	4	17	18
3862	14	–			–
	18		–	–	
	19		–	–	
	20	–			–

Appendix H (continued).

4383

3862	4	8	12	20
14	–			–
18		–	–	
19		–	–	
20	–			–

3822

3862	2	4	7	12
14	–			–
18		–	–	
19		–	–	
20	–			–

6273

3862	2	4	9	15
14	–			–
18		–	–	
19		–	–	
20	–			–

4862

3862	1	4	9	13
14	–			–
18		–	–	
19		–	–	
20	–			–

9323

3862	1	4	7	9
14	–			–
18		–	–	
19		–	–	
20	–			–

8594

3862	9	18	22	42
14	–			–
18		–	–	
19		–	–	
20	–			–

5124

3862	1	8	9	10
14	–			–
18		–	–	
19		–	–	
20	–			–

3879

3862	15	16	17	20
14	–			–
18		–	–	
19		–	–	
20	–			–

Appendix H (continued).

7156

3862	14	14			
	18				
	19				
	20				

v153

3862	14	4	8	11	15
	18				
	19				
	20				

pbm 772

3862	14	11	14		
	18				
	19				
	20				

6964

6963	14	16	17	19	20
	16				
	17				
	20				

9037

6963	14	14	16	17	20
	16				
	17				
	20				

8560

6963	14	5	7	20	21
	16				
	17				
	20				

8561

6963	14	15	20	21	27
	16				
	17				
	20				

7319

6963	14	5	11	21	29
	16				
	17				
	20				

Appendix H (continued).

5734

		5	6	11	
6963	14	+++	+++	+++	
	16	+++	+++	+++	
	17	+++	+++	+++	
	20	+++	+++	+++	

grw

34

		25	27	45	46
6963	14	+++			+++
	16		+++	+++	
	17		+++	+++	
	20	+++			+++

3583

		14	17	21	24
6963	14	+++			+++
	16		+++	+++	
	17		+++	+++	
	20	+++			+++

8614

		1	2	8	15
6963	14	+++			+++
	16		+++	+++	
	17		+++	+++	
	20	+++			+++

8652

		8	9	13	17
6963	14	+++			+++
	16		+++	+++	
	17		+++	+++	
	20	+++			+++

8653

		1	5	7	11
6963	14	+++			+++
	16		+++	+++	
	17		+++	+++	
	20	+++			+++

8656

		16	7		
6963	14	+++	+++		
	16	+++	+++		
	17	+++	+++		
	20	+++	+++		

9018

		7	10	11	18
6963	14	+++			+++
	16		+++	+++	
	17		+++	+++	
	20	+++			+++

Appendix H (continued).

8657

6963		9	5		
	14	+++	+++		
	16	+++	+++		
	17	+++	+++		
	20	+++	+++		

8661

6963		11	5		
	14	+++	+++		
	16	+++	+++		
	17	+++	+++		
	20	+++	+++		

3488

6963		2	7	11	18
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

9305

6963		8	10	16	17
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

9315

6963		3	4	17	18
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

4383

6963		4	8	12	20
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

3822

6963		2	4	7	12
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

6273

6963		2	4	9	15
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

Appendix H (continued).

4862

6963		1	4	9	13
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

9323

6963		1	4	7	9
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

8594

6963		9	18	22	42
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

5124

6963		1	8	9	10
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

3879

6963		15	16	17	20
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

7156

6963		14
	14	$_{+}+^{+}$
	16	$_{+}+^{+}$
	17	$_{-}+^{+}$
	20	$_{+}+^{-}$

v153

6963		4	8	11	15
	14	$_{+}+^{+}$			$_{+}+^{+}$
	16		$_{+}+^{+}$	$_{+}+^{+}$	
	17		$_{-}+^{+}$	$_{+}+^{-}$	
	20	$_{+}+^{+}$			$_{+}+^{-}$

pbm 772

6963		11	4
	14	$_{+}+^{+}$	$_{+}+^{+}$
	16	$_{+}+^{+}$	$_{+}+^{+}$
	17	$_{-}+^{+}$	$_{-}+^{+}$
	20	$_{+}+^{-}$	$_{+}+^{-}$

Appendix H (continued).

9037

6964	11	14		
16	+/+	+/+		
17	+/+	+/+		
19	+/+	+/+		
20	+/+	+/+		

8560

6964	16	17	19	20
16	+/+			-/+
17		+/+	+/+	
19		+/+	-/+	
20	+/+			+/-

8561

6964	15	20	21	27
16	+/-			+/+
17		-/+	+/+	
19		+/+	+/-	
20	+/+			-/+

7319

6964	5	11	21	29
16	+/+			+/+
17		+/+	+/+	
19		+/+	+/+	
20	+/+			+/+

5734

6964	5	6	11	
16	+/+	+/+	+/+	
17	+/+	+/+	+/+	
19	+/+	+/+	+/+	
20	+/+	+/+	+/+	

grw 34

6964	25	27	45	46
16	+/+			+/+
17		+/+	+/+	
19		+/+	+/+	
20	+/+			+/+

3583

6964	14	17	21	24
16	+/+			+/+
17		+/+	+/+	
19		+/+	+/+	
20	+/+			+/+

8614

6964	1	2	8	15
16	+/+			+/+
17		+/+	+/+	
19		+/+	+/+	
20	+/+			+/+

Appendix H (continued).

8652

6964		8	9	13	17
	16	+++ f			+++ f
	17		+++	+++	
	19		+++	+++	
	20	+++			+++

8653

6964		1	5	7	11
	16	+++			+++
	17		+++	+++	
	19		+++	+++	
	20	+++			+++

8656

6964		16	7		
	16	+++	+++		
	17	+++	+++		
	19	+++	+++		
	20	+++	+++		

9018

6964		7	10	11	18
	16	+++			+++
	17		+++	+++	
	19		+++	+++	
	20	+++			+++

8657

6964		9	5		
	16	+++	+++		
	17	+++	+++		
	19	+++	+++		
	20	+++	+++		

8661

6964		11	5		
	16	+++	+++		
	17	+++	+++		
	19	+++	+++		
	20	+++	+++		

3488

6964		2	7	11	18
	16	–			–
	17		–	–	
	19		–	–	
	20	–			–

9305

6964		8	10	16	17
	16	–			–
	17		–	–	
	19		–	–	
	20	–			–

Appendix H (continued).

9315

		3	4	17	18
6964	16	–			–
	17		–	–	
	19		–	–	
	20	–			–

4383

		4	8	12	20
6964	16	–			–
	17		–	–	
	19		–	–	
	20	–			–

3822 et

		2	4	7	12
6964	16	–			–
	17		–	–	
	19		–	–	
	20	–			–

6273

		2	4	9	15
6964	16	–			–
	17		–	–	
	19		–	–	
	20	–			–

4862

		1	4	9	13
6964	16	–			–
	17		–	–	
	19		–	–	
	20	–			–

9323

		1	4	7	9
6964	16	–			–
	17		–	–	
	19		–	–	
	20	–			–

8594

		9	18	22	42
6964	16	–			–
	17		–	–	
	19		–	–	
	20	–			–

5124

		1	8	9	10
6964	16	–			–
	17		–	–	
	19		–	–	
	20	–			–

Appendix H (continued).

3879

6964	15	16	17	20
16	–			–
17		–	–	
19		–	–	
20	–			–

7156

6964	14			
16	+++			
17	+++			
19	+++			
20	+++			

153

6964	4	8	11	15
16	+++			+++
17		+++	+++	
19		+++	+++	
20	+++			+++

772

6964	11	14		
16	+++	+++		
17	+++	+++		
19	+++	+++		
20	+++	+++		

8560

9037	5	7	20	21
14	+++			+++
16		+++	+++	
17		+++	+++	
20	+++			+++

8561

9037	15	20	21	27
14	+++	+++	+++	+++
16	+++	+++	+++	+++
17	+++	+++	+++	+++
20	+++	+++	+++	+++

7319

9037	5	11	21	29
14	+++			+++
16		+++	+++	
17		+++	+++	
20	+++			+++

5734

9037	5	6	11	
14	+++	+++	+++	
16	+++	+++	+++	
17	+++	+++	+++	
20	+++	+++	+++	

Appendix H (continued).

grw
34

9037	14	25	27	45	46
	16				
	17				
	20				

3583

9037	14	14	17	21	24
	16				
	17				
	20				

8614

9037	14	1	2	8	15
	16				
	17				
	20				

8652

9037	14	8	9	13	17
	16				
	17				
	20				

8653

9037	14	1	5	7	11
	16				
	17				
	20				

8656

9037	14	16	7
	16		
	17		
	20		

9018

9037	14	7	10	11	18
	16				
	17				
	20				

8657

9037	14	9	5
	16		
	17		
	20		

Appendix H (continued).

8661

9037		11	5		
	14	+++	+++		
	16	+++	+++		
	17	+++	+++		
	20	+++	+++		

3488

9037		2	7	11	18
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

9305

9037		8	10	16	17
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

9315

9037		3	4	17	18
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

4383

9037		4	8	12	20
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

3822 et

9037		2	4	7	12
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

6273

9037		2	4	9	15
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

4862

9037		1	4	9	13
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

Appendix H (continued).

9323

		1	4	7	9
9037	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

8594

		9	18	22	42
9037	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

5124

		1	8	9	10
9037	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

3879

		15	16	17	20
9037	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

7156

14

9037	14	+++			
	16	+++			
	17	+++			
	20	+++			

153

		4	8	11	15
9037	14	+++			+++
	16		+++	+++	
	17		+++	+++	
	20	+++			+++

pbm

772

		11	14		
9037	14	+++	+++		
	16	+++	+++		
	17	+++	+++		
	20	+++	+++		

8561

		15	20	21	27
8560	5	+++			+++
	7		+++	+++	
	20		+++	+++	
	21	+++			+++

Appendix H (continued).

7319

		5	11	21	29
8560	5	+++			+++
	7		+++	+++	
	20		+++	+++	
	21	+++			+++

5734

		5	6	11	
8560	5	+++	+++	+++	
	7	+++	+++	+++	
	20	+++	+++	+++	
	21	+++	+++	+++	

grw
34

		25	27	45	46
8560	5	+++			+++
	7		+++	+++	
	20		+++	+++	
	21	+++			+++

3583

		14	17	21	24
8560	5	+++			+++
	7		+++	+++	
	20		+++	+++	
	21	+++			+++

8614

		1	2	8	15
8560	5	+++			+++
	7		+++	+++	
	20		+++	+++	
	21	+++			+++

8652

		8	9	13	17
8560	5	+++ f			+++ f
	7		+++	+++	
	20		+++	+++	
	21	+++			+++

8653

		1	5	7	11
8560	5	+++			+++
	7		+++	+++	
	20		+++	+++	
	21	+++			+++

8656

		16	7		
8560	5	+++	+++		
	7	+++	+++		
	20	+++	+++		
	21	+++	+++		

Appendix H (continued).

9018

8560	7	10	11	18
5	+/+			+/+
7		+/+	+/+	
20		+/+	+/+	
21	+/+			+/+

8657

8560	9	5
5	+/+	+/+
7	+/+	+/+
20	+/+	+/+
21	+/+	+/+

8661

8560	11	5
5	+/+	+/+
7	+/+	+/+
20	+/+	+/+
21	+/+	+/+

3488

8560	2	7	11	18
5	–			–
7		–	–	
20		–	–	
21	–			–

9305

8560	8	10	16	17
5	–			–
7		–	–	
20		–	–	
21	–			–

9315

8560	3	4	17	18
5	–			–
7		–	–	
20		–	–	
21	–			–

4383

8560	4	8	12	20
5	–			–
7		–	–	
20		–	–	
21	–			–

3822et

8560	2	4	7	12
5	–			–
7		–	–	
20		–	–	
21	–			–

Appendix H (continued).

6273

8560		2	4	9	15
	5	–			–
	7		–	–	
	20		–	–	
	21	–			–

4862

8560		1	4	9	13
	5	–			–
	7		–	–	
	20		–	–	
	21	–			–

9323

8560		1	4	7	9
	5	–			–
	7		–	–	
	20		–	–	
	21	–			–

8594

8560		9	18	22	42
	5	–			–
	7		–	–	
	20		–	–	
	21	–			–

5124

8560		1	8	9	10
	5	–			–
	7		–	–	
	20		–	–	
	21	–			–

3879

8560		15	16	17	20
	5	–			–
	7		–	–	
	20		–	–	
	21	–			–

7156

8560		14
	5	$_{+}^{+}$
	7	$_{+}^{+}$
	20	$_{+}^{+}$
	21	$_{+}^{+}$

v153

8560		4	8	11	15
	5	$_{+}^{+}$			$_{+}^{+}$
	7		$_{+}^{+}$	$_{+}^{+}$	
	20		$_{+}^{+}$	$_{+}^{+}$	
	21	$_{+}^{+}$			$_{+}^{+}$

Appendix H (continued).

pbm
772

		11	14		
8560	5	+/+	+/+		
	7	+/+	+/+		
	20	+/+	+/+		
	21	+/+	+/+		

7319

		16	17	19	20
8561	15	+/+			+/+
	20		+/+	+/+	
	21		+/+	+/+	
	27	+/+			+/+

5734

		5	6	11	
8561	15	+/+	+/+	+/+	
	20	+/+	+/+	+/+	
	21	+/+	+/+	+/+	
	27	+/+	+/+	+/+	

grw
34

		25	27	45	46
8561	15	+/+	+/+	–	+/+
	20	+/+	+/+	–	+/+
	21	+/+	+/+	+/+	+/+
	27	–	–	+/+	+/+

3583

		14	17	21	24
8561	15	+/+			+/+
	20		+/+	+/+	
	21		+/+	+/+	
	27	+/+			+/+

8614

		1	2	8	15
8561	15	+/+			+/+
	20		+/+	+/+	
	21		+/+	+/+	
	27	+/+			+/+

8652

		8	9	13	17
8561	15	+/+ f			+/+ f
	20		+/+	+/+	
	21		+/+	+/+	
	27	+/+			+/+

8653

		1	5	7	11
8561	15	+/+			+/+
	20		+/+	+/+	
	21		+/+	+/+	
	27	+/+			+/+

Appendix H (continued).

8656

		16	7		
8561	15	+/+	+/+		
	20	+/+	+/+		
	21	+/+	+/+		
	27	+/+	+/+		

9018

		7	10	11	18
8561	15	-/+			+/+
	20		+/+	+/+	
	21		+/+	-/-	
	27	+/+			+/+

8657

		9	5		
8561	15	-/+	+/+		
	20	+/+	-/+		
	21	+/-	+/+		
	27	+/+	+/+		

8661

		11	5		
8561	15	-/+	+/+		
	20	+/-	+/-		
	21	+/+	-/+		
	27	-/+	+/+		

3488

		2	7	11	18
8561	15	–			–
	20		–	–	
	21		–	–	
	27	–			–

9305

		8	10	16	17
8561	15	–			–
	20		–	–	
	21		–	–	
	27	–			–

9315

		3	4	17	18
8561	15	–			–
	20		–	–	
	21		–	–	
	27	–			–

4383

		4	8	12	20
8561	15	–			–
	20		–	–	
	21		–	–	
	27	–			–

Appendix H (continued).

3822 et

8561	2	4	7	12
15	–			–
20		–	–	
21		–	–	
27	–			–

6273

8561	2	4	9	15
15	–			–
20		–	–	
21		–	–	
27	–			–

4862

8561	1	4	9	13
15	–			–
20		–	–	
21		–	–	
27	–			–

9323

8561	1	4	7	9
15	–			–
20		–	–	
21		–	–	
27	–			–

8594

8561	9	18	22	42
15	–			–
20		–	–	
21		–	–	
27	–			–

5124

8561	1	8	9	10
15	–	–	–	–
20	–	–	–	–
21	–	–	–	–
27	–	–	–	–

3879

8561	15	16	17	20
15	–			–
20		–	–	
21		–	–	
27	–			–

7156

8561	14			
15	+/+			
20	-/+			
21	+/+			
27	+/-			

Appendix H (continued).

v153

		4	8	11	15
8561	15	+/+			+/+
	20		-/+	-/+	
	21		+/+	+/+	
	27	+/+			+/+

pbm

772

		11	14		
8561	15	+/+	+/+		
	20	+/+	+/-		
	21	+/-	-/+		
	27	+/+	-/+		

5734

		5	6	11	
7319	5	-/+	+/+	-/+	
	11	+/+	+/+	+/+	
	21	-/+	+/-	-/+	
	29	+/+	+/+	+/+	

grw

34

		25	27	45	46
7319	5	–	+/+	+/+	+/+
	11	+/+	+/+	+/+	+/+
	21	+/+	+/+	–	–
	29	-/+	+/+	+/+	–

3583

		14	17	21	24
7319	5	-/+	+/+	+/-	+/+
	11	+/+	+/+	-/+	+/+
	21	+/+	+/+	+/+	+/+
	29	-/+	+/+	+/–	+/+

8614

		1	2	8	15
7319	5	+/+			+/+
	11		+/+	+/+	
	21		+/+	+/+	
	29	+/+			+/+

8652

		8	9	13	17
7319	5	+/+ f			+/+ f
	11		+/+	+/+	
	21		+/+	+/+	
	29	+/+			+/+

8653

		1	5	7	11
7319	5	+/+	+/+	+/+	+/+
	11	+/+	+/+	+/+	+/+
	21	+/+	+/+	+/+	+/+
	29	+/+	+/+	+/+	+/+

Appendix H (continued).

8656

7319		16	7		
	5	+++	+++		
	11	+++	+++		
	21	+++	+++		
	29	+++	+++		

9018

7319		7	10	11	18
	5	+++			+++
	11		+++	+++	
	21		+++	+++	
	29	+++			+++

8657

7319		9	5		
	5	+++	+++		
	11	+++	+++		
	21	+++	+++		
	29	+++	+++		

8661

7319		11	5		
	5	+++	+++		
	11	+++	+++		
	21	+++	+++		
	29	+++	+++		

3488

7319		2	7	11	18
	5	–			–
	11		–	–	
	21		–	–	
	29	–			–

9305

7319		8	10	16	17
	5	–			–
	11		–	–	
	21		–	–	
	29	–			–

9315

7319		3	4	17	18
	5	–			–
	11		–	–	
	21		–	–	
	29	–			–

4383

7319		4	8	12	20
	5	–			–
	11		–	–	
	21		–	–	
	29	–			–

Appendix H (continued).

3822 et

7319	2	4	7	12
5	–			–
11		–	–	
21		–	–	
29	–			–

6273

7319	2	4	9	15
5	–			–
11		–	–	
21		–	–	
29	–			–

4862

7319	1	4	9	13
5	–	–	–	–
11	–	–	–	–
21	–	–	–	–
29	–	–	–	–

9323

7319	1	4	7	9
5	–	–	–	–
11	–	–	–	–
21	–	–	–	–
29	–	–	–	–

8594

7319	9	18	22	42
5	–			–
11		–	–	
21		–	–	
29	–			–

5124

7319	1	8	9	10
5	–			–
11		–	–	
21		–	–	
29	–			–

3879

7319	15	16	17	20
5	–			–
11		–	–	
21		–	–	
29	–			–

7156

7319	14			
5	+++			
11	+++			
21	+++			
29	+++			

Appendix H (continued).

v153

		4	8	11	15
7319	5	+/+			+/+
	11		+/+	+/+	
	21		+/+	+/+	
	29	+/+			+/+

pbm7
72

		11	14		
7319	5	+/+	+/+		
	11	+/+	+/+		
	21	+/+	+/+		
	29	+/+	+/+		

grw
34

		5	10	11	
5734	5	+/+	+/+	+/+	
	6	+/+	+/+	+/+	
	11	+/+	+/+	+/+	
		+/+	+/+	+/+	

3583

		14	17	21	24
5734	5	+/+	+/+	+/+	+/+
	6	+/+	+/+	+/+	+/+
	11	+/+	+/+	+/+	+/+
		+/+	+/+	+/+	+/+

8614

		1	2	8	15
5734	5	+/+	+/+	+/+	+/+
	6	+/+	+/+	+/+	+/+
	11	+/+	+/+	+/+	+/+
		+/+	+/+	+/+	+/+

8652

		8	9	13	17
5734	5	+/+ f			+/+ f
	6		+/+	+/+	
	11		+/+	+/+	
		+/+			+/+

8653

		1	5	7	11
5734	5	+/+	+/+	+/+	+/+
	6	+/+	+/+	+/+	+/+
	11	+/+	+/+	+/+	+/+
		+/+	+/+	+/+	+/+

8656

		16	7		
5734	5	+/+	+/+		
	6	+/+	+/+		
	11	+/+	+/+		
		+/+	+/+		

Appendix H (continued).

9018

5734		7	10	11	18
	5	+++	+++	+++	+++
	6	+++	+++	+++	+++
	11	+++	+++	+++	+++
		+++	+++	+++	+++

8657

5734		9	5		
	5	+++	+++		
	6	+++	+++		
	11	+++	+++		
		+++	+++		

8661

5734		11	5		
	5	+++	+++		
	6	+++	+++		
	11	+++	+++		
		+++	+++		

3488

5734		2	7	11	18
	5	–			–
	6		–	–	
	11		–	–	
		–			–

9305

5734		8	10	16	17
	5	–			–
	6		–	–	
	11		–	–	
		–			–

9315

5734		3	4	17	18
	5	–			–
	6		–	–	
	11		–	–	
		–			–

4383

5734		4	8	12	20
	5	–			–
	6		–	–	
	11		–	–	
		–			–

3822 et

5734		2	4	7	12
	5	–			–
	6		–	–	
	11		–	–	
		–			–

Appendix H (continued).

6273

		2	4	9	15
5734	5	–			–
	6		–	–	
	11		–	–	
		–			–

4862

		1	4	9	13
5734	5	–			–
	6		–	–	
	11		–	–	
		–			–

9323

		1	4	7	9
5734	5	–			–
	6		–	–	
	11		–	–	
		–	–	–	–

8594

		9	18	22	42
5734	5	–			–
	6		–	–	
	11		–	–	
		–			–

5124

		1	8	9	10
5734	5	–			–
	6		–	–	
	11		–	–	
		–			–

3879

		15	16	17	20
5734	5	–			–
	6		–	–	
	11		–	–	
		–			–

7156

14

5734	5	+++			
	6	+++			
	11	+++			
		+++			

v153

		4	8	11	15
5734	5	+++			+++
	6		+++	+++	
	11		+++	+++	
		+++			+++

Appendix H (continued).

pbm
772

		11	14		
5734	5	+++	+++		
	6	+++	+++		
	11	+++	+++		
		+++	+++		

3583

		14	17	21	24
grw 34	25	+++			+++
	27		+++	+++	
	45		+++	+++	
	46	+++			+++

8614

		1	2	8	15
grw 34	25	+++			+++
	27		+++	+++	
	45		+++	+++	
	46	+++			+++

8652

		8	9	13	17
grw 34	25	+++ f			+++ f
	27		+++	+++	
	45		+++	+++	
	46	+++			+++

8653

		1	5	7	11
grw 34	25	+++			+++
	27		+++	+++	
	45		+++	+++	
	46	+++			+++

8656

		16	7		
grw 34	25	+++	+++		
	27	+++	+++		
	45	+++	+++		
	46	+++	+++		

9018

		7	10	11	18
grw 34	25	+++			+++
	27		+++	+++	
	45		+++	+++	
	46	+++			+++

8657

		9	5		
grw 34	25	+++	+++		
	27	+++	+++		
	45	+++	+++		
	46	+++	+++		

Appendix H (continued).

8661

grw 34	11	5		
25	+++	+++		
27	+++	+++		
45	+++	+++		
46	+++	+++		

3488

grw 34	2	7	11	18
25	–			–
27		–	–	
45		–	–	
46	–			–

9305

grw 34	8	10	16	17
25	–			–
27		–	–	
45		–	–	
46	–			–

9315

grw 34	3	4	17	18
25	–	–	–	–
27	–	–	–	–
45	–	–	–	–
46	–	–	–	–

4383

grw 34	4	8	12	20
25	–			–
27		–	–	
45		–	–	
46	–			–

3822 et

grw 34	2	4	7	12
25	–			–
27		–	–	
45		–	–	
46	–			–

6273

grw 34	2	4	9	15
25	–			–
27		–	–	
45		–	–	
46	–			–

4862

grw 34	1	4	9	13
25	–	–	–	–
27	–	–	–	–
45	–	–	–	–
46	–	–	–	–

Appendix H (continued).

9323

		1	4	7	9
grw 34	25	–			–
	27		–	–	
	45		–	–	
	46	–			–

8594

		9	18	22	42
grw 34	25	–			–
	27		–	–	
	45		–	–	
	46	–			–

5124

		1	8	9	10
grw 34	25	–			–
	27		–	–	
	45		–	–	
	46	–			–

3879

		15	16	17	20
grw34	25	–			–
	27		–	–	
	45		–	–	
	46	–			–

7156

		14
grw 34	25	+
	27	+
	45	+
	46	+

v153

		4	8	11	15
grw 34	25	+	+	+	+
	27	+	+	+	+
	45	+	+	+	+
	46	–	–		

pbm 772

		11	14
grw 34	25	+	+
	27	+	+
	45	+	+
	46	+	+

8614

		4	8	11	15
3583	25	+			+
	27		+	+	
	45		+	+	
	46	+			+

Appendix H (continued).

8652

		8	9	13	17
3583	14	+f+			+f+
	17		+ +	+ +	
	21		+ +	+ +	
	24	+ +			+ +

8653

		1	5	7	11
3583	14	+ +			+ +
	17		+ +	+ +	
	21		+ +	+ +	
	24	+ +			+ +

8656

		16	7		
3583	14	+ +	+ +		
	17	+ +	+ +		
	21	+ +	+ +		
	24	+ +	+ +		

9018

		7	10	11	18
3583	14	+ +			+ +
	17		+ +	+ +	
	21		+ +	+ +	
	24	+ +			+ +

8657

		9	5		
3583	14	+ +	+ +		
	17	+ +	+ +		
	21	+ +	+ +		
	24	+ +	+ +		

8661

		11	5		
3583	14	+ +	+ +		
	17	+ +	+ +		
	21	+ +	+ +		
	24	+ +	+ +		

3488

		2	7	11	18
3583	14	–			–
	17		–	–	
	21		–	–	
	24	–			–

9305

		8	10	16	17
3583	14	–			–
	17		–	–	
	21		–	–	
	24	–			–

Appendix H (continued).

9315

3583		3	4	17	18
	14	–			–
	17		–	–	
	21		–	–	
	24	–			–

4383

3583		4	8	12	20
	14	–			–
	17		–	–	
	21		–	–	
	24	–			–

3822 et

3583		2	4	7	12
	14	–			–
	17		–	–	
	21		–	–	
	24	–			–

6273

3583		2	4	9	15
	14	–			–
	17		–	–	
	21		–	–	
	24	–			–

4862

3583		1	4	9	13
	14	–			–
	17		–	–	
	21		–	–	
	24	–			–

9323

3583		1	4	7	9
	14	–			–
	17		–	–	
	21		–	–	
	24	–			–

8594

3583		9	18	22	42
	14	–			–
	17		–	–	
	21		–	–	
	24	–			–

5124

3583		1	8	9	10
	14	–			–
	17		–	–	
	21		–	–	
	24	–			–

Appendix H (continued).

3879

		15	16	17	20
3583	14	–			–
	17		–	–	
	21		–	–	
	24	–			–

7156

		14
3583	14	+⁺
	17	+⁺
	21	+⁺
	24	+⁺

v153

		4	8	11	15
3583	14	+⁺			+⁺
	17		+⁺	+⁺	
	21		+⁺	+⁺	
	24	+⁺			+⁺

pbm7 72

		11	14
3583	14	+⁺	+⁺
	17	+⁺	+⁺
	21	+⁺	+⁺
	24	+⁺	+⁺

8652

		8	9	13	17
8614	1	+⁺			+⁺
	2		+⁺	+⁺	
	8		+⁺	+⁺	
	15	+⁺			+⁺

8653

		1	5	7	11
8614	1	+⁺			+⁺
	2		+⁺	+⁺	
	8		+⁺	+⁺	
	15	+⁺			+⁺

8656

		16	7
8614	1	+⁺	+⁺
	2	+⁺	+⁺
	8	+⁺	+⁺
	15	+⁺	+⁺

9018

		7	10	11	18
8614	1	+⁺			+⁺
	2		+⁺	+⁺	
	8		+⁺	+⁺	
	15	+⁺			+⁺

Appendix H (continued).

8657

8614		9	5		
	1	+++	+++		
	2	+++	+++		
	8	+++	+++		
	15	+++	+++		

8661

8614		11	5		
	1	+++	+++		
	2	+++	+++		
	8	+++	+++		
	15	+++	+++		

3488

8614		2	7	11	18
	1	–			–
	2		–	–	
	8		–	–	
	15	–			–

9305

8614		8	10	16	17
	1	–			–
	2		–	–	
	8		–	–	
	15	–			–

9315

8614		3	4	17	18
	1	–			–
	2		–	–	
	8		–	–	
	15	–			–

4383

8614		4	8	12	20
	1	–			–
	2		–	–	
	8		–	–	
	15	–			–

3822
et

8614		2	4	7	12
	1	–			–
	2		–	–	
	8		–	–	
	15	–			–

6273

8614		2	4	9	15
	1	–			–
	2		–	–	
	8		–	–	
	15	–			–

Appendix H (continued).

4862

8614	1	4	9	13
1	–			–
2		–	–	
8		–	–	
15	–			–

9323

8614	1	4	7	9
1	–			–
2		–	–	
8		–	–	
15	–			–

8594

8614	9	18	22	42
1	–			–
2		–	–	
8		–	–	
15	–			–

5124

8614	1	8	9	10
1	–			–
2		–	–	
8		–	–	
15	–			–

3879

8614	15	16	17	20
1	–			–
2		–	–	
8		–	–	
15	–			–

7156

14

8614	
1	+
2	+
8	+
15	+

v153

8614	4	8	11	15
1	+			+
2		+	+	
8		+	+	
15	+			+

pbm 772

8614	11	14
1	+	+
2	+	+
8	+	+
15	+	+

Appendix H (continued).

8653

8652	1	5	7	11
8	+++			+++
9		+++	+++	
13		+++	+++	
17	+++			+++

8656

8652	16	7		
8	+++	+++		
9	+++	+++		
13	+++	+++		
17	+++	+++		

9018

8652	7	10	11	18
8	+++			+++
9		+++	+++	
13		+++	+++	
17	+++			+++

8657

8652	9	5		
8	+++	+++		
9	+++	+++		
13	+++	+++		
17	+++	+++		

8661

8652	11	5		
8	+++	+++		
9	+++	+++		
13	+++	+++		
17	+++	+++		

3488

8652	2	7	11	18
8	–			–
9	–	–	–	
13	–	–	–	
17	–			–

9305

8652	8	10	16	17
8	–			–
9	–	–	–	
13	–	–	–	
17	–			–

9315

8652	3	4	17	18
8	–			–
9	–	–	–	
13	–	–	–	
17	–			–

Appendix H (continued).

4383

8652		4	8	12	20
	8	–			–
	9	–	–	–	
	13	–	–	–	
	17	–			–

3822 et

8652		2	4	7	12
	8	–			–
	9	–	–	–	
	13	–	–	–	
	17	–			–

6273

8652		2	4	9	15
	8	–			–
	9	–	–	–	
	13	–	–	–	
	17	–			–

4862

8652		1	4	9	13
	8	–			–
	9	–	–	–	
	13	–	–	–	
	17	–			–

9323

8652		1	4	7	9
	8	–			–
	9	–	–	–	
	13	–	–	–	
	17	–			–

8594

8652		9	18	22	42
	8	–			–
	9		–	–	
	13		–	–	
	17	–			–

5124

8652		1	8	9	10
	8	–			–
	9		–	–	
	13		–	–	
	17	–			–

3879

8652		15	16	17	20
	8	–			–
	9	–	–	–	
	13	–	–	–	
	17	–			–

Appendix H (continued).

7156

		14
8652	8	+/+
	9	+/+
	13	+/+
	17	+/+

v153

		4	8	11	15
8652	8	+/+			+/+
	9		+/+	+/+	
	13		+/+	+/+	
	17	+/+			+/+

pbm 772

		11	14
8652	8	+/+	+/+
	9	+/+	+/+
	13	+/+	+/+
	17	+/+	+/+

8656

		16	7		
8653	1	+/+			+/+
	5		+/+	+/+	
	7		+/+	+/+	
	11	+/+			+/+

9018

		7	10	11	18
8653	1	+/+	+/+	+/+	+/+
	5	+/+	+/+	+/+	+/+
	7	+/+	+/+	+/+	+/+
	11	+/+	+/+	+/+	+/+

8657

		9	5		
8653	1	+/+	+/+		
	5	+/+	+/+		
	7	+/+	+/+		
	11	+/+	+/+		

8661

		11	5		
8653	1	+/+	+/+		
	5	+/+	+/+		
	7	+/+	+/+		
	11	+/+	+/+		

3488

		2	7	11	18
8653	1	–			–
	5	–	–	–	
	7	–	–	–	
	11	–			–

Appendix H (continued).

9305

		8	10	16	17
8653	1	–			–
	5	–	–	–	
	7	–	–	–	
	11	–			–

9315

		3	4	17	18
8653	1	–			–
	5	–	–	–	
	7	–	–	–	
	11	–			–

4383

		4	8	12	20
8653	1	–			–
	5	–	–	–	
	7	–	–	–	
	11	–			–

3822et

		2	4	7	12
8653	1	–			–
	5	–	–	–	
	7	–	–	–	
	11	–			–

6273

		2	4	9	15
8653	1	–			–
	5	–	–	–	
	7	–	–	–	
	11	–			–

4862

		1	4	9	13
8653	1	–			–
	5	–	–	–	
	7	–	–	–	
	11	–			–

9323

		1	4	7	9
8653	1	–			–
	5	–	–	–	
	7	–	–	–	
	11	–			–

8594

		9	18	22	42
8653	1	–			–
	5	–	–	–	
	7	–	–	–	
	11	–			–

Appendix H (continued).

5124

		1	8	9	10
8653	1	–			–
	5	–	–	–	
	7	–	–	–	
	11	–			–

3879

		15	16	17	20
8653	1	–			–
	5	–	–	–	
	7	–	–	–	
	11	–			–

7156

		14
8653	1	+/+
	5	+/+
	7	+/+
	11	+/+

v153

		4	8	11	15
8653	1	+/+			+/+
	5		+/+	+/+	
	7		+/+	+/+	
	11	+/+			+/+

pbm 772

		11	14
8653	1	+/+	+/+
	5	+/+	+/+
	7	+/+	+/+
	11	+/+	+/+

9018

		7	10	11	18
8656	16	+/+	+/+	+/+	+/+
	7	+/+	+/+	+/+	+/+

8657

		9	5
8656	16	+/+	+/+
	7	+/+	+/+

8661

		11	5
8656	16	+/+	+/+
	7	+/+	+/+

Appendix H (continued).

3488

8656	16	2	7	11	18
		–	–	–	–
	7	–	–	–	–

9305

8656	16	8	10	16	17
		–	–	–	–
	7	–	–	–	–

9315

8656	16	3	4	17	18
		–	–	–	–
	7	–	–	–	–

4383

8656	16	4	8	12	20
		–	–	–	–
	7	–	–	–	–

3822
et

8656	16	2	4	7	12
		–	–	–	–
	7	–	–	–	–

6273

8656	16	2	4	9	15
		–	–	–	–
	7	–	–	–	–

4862

8656	16	1	4	9	13
		–	–	–	–
	7	–	–	–	–

9323

8656	16	1	4	7	9
		–	–	–	–
	7	–	–	–	–

Appendix H (continued).

8594

		9	18	22	42
8656	16	–	–	–	–
	7	–	–	–	–

5124

		1	8	9	10
8656	16	–	–	–	–
	7	–	–	–	–

3879

		15	16	17	20
8656	16	–	–	–	–
	7	–	–	–	–

7156

		14			
8656	16	+++			
	7	+++			
		+++			
		+++			

v153

		4	8	11	15
8656	16	+++	+++	+++	+++
	7	+++	+++	+++	+++

pbm 772

		11	14		
8656	16	+++	+++		
	7	+++	+++		
		+++	+++		
		+++	+++		

8657

		9	5		
9018	7	+++			+++
	10		+++	+++	
	11		+++	+++	
	18	+++			+++

8661

		11	5		
9018	7	+++	+++		
	10	+++	+++		
	11	+++	+++		
	18	+++	+++		

Appendix H (continued).

3488

9018	7	2	7	11	18
		–			–
	10		–	–	
	11		–	–	
	18	–			–

9305

9018	7	8	10	16	17
		–			–
	10		–	–	
	11		–	–	
	18	–			–

9315

9018	7	3	4	17	18
		–			–
	10		–	–	
	11		–	–	
	18	–			–

4383

9018	7	4	8	12	20
		–			–
	10		–	–	
	11		–	–	
	18	–			–

3822 et

9018	7	2	4	7	12
		–			–
	10		–	–	
	11		–	–	
	18	–			–

6273

9018	7	2	4	9	15
		–			–
	10		–	–	
	11		–	–	
	18	–			–

4862

9018	7	1	4	9	13
		–			–
	10		–	–	
	11		–	–	
	18	–			–

9323

9018	7	1	4	7	9
		–			–
	10		–	–	
	11		–	–	
	18	–			–

Appendix H (continued).

8594

9018	9	18	22	42
7	–			–
10		–	–	
11		–	–	
18	–			–

5124

9018	1	8	9	10
7	–			–
10		–	–	
11		–	–	
18	–			–

3879

9018	15	16	17	20
7	–			–
10		–	–	
11		–	–	
18	–			–

7156

9018	14
7	+++
10	+++
11	+++
18	+++

v153

9018	4	8	11	15
7	+++			+++
10		+++	+++	
11		+++	+++	
18	+++			+++

pbm7 72

9018	11	14
7	+++	+++
10	+++	+++
11	+++	+++
18	+++	+++

8661

8657	11	5
14	+++	+++
16	+++	+++
17	+++	+++
20	+++	+++

3488

8657	2	7	11	18
14	–			–
16		–	–	
17		–	–	
20	–			–

Appendix H (continued).

9305

8657		8	10	16	17
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

9315

8657		3	4	17	18
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

7866

8657		1	7	10	11
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

4383

8657		4	8	12	20
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

3822 et

8657		2	4	7	12
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

6273

8657		2	4	9	15
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

4862

8657		1	4	9	13
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

9323

8657		1	4	7	9
	14	–			–
	16		–	–	
	17		–	–	
	20	–			–

Appendix H (continued).

8594

8657	9	18	22	42
14	–			–
16		–	–	
17		–	–	
20	–			–

5124

8657	1	8	9	10
14	–			–
16		–	–	
17		–	–	
20	–			–

3879

8657	15	16	17	20
14	–			–
16		–	–	
17		–	–	
20	–			–

7156

8657	14
14	+++
16	+++
17	+++
20	+++

v153

8657	4	8	11	15
14	+++			+++
16		+++	+++	
17		+++	+++	
20	+++			+++

pbm 772

8657	11	14
14	+++	+++
16	+++	+++
17	+++	+++
20	+++	+++

3488

8661	2	7	11	18
11	–	–	–	–
5	–	–	–	–

9305

8661	8	10	16	17
11	–	–	–	–
5	–	–	–	–

Appendix H (continued).

9315

		3	4	17	18
8661	11	–	–	–	–
	5	–	–	–	–

4383

		4	8	12	20
8661	11	–	–	–	–
	5	–	–	–	–

3822 et

		2	4	7	12
8661	11	–	–	–	–
	5	–	–	–	–

6273

		2	4	9	15
8661	11	–	–	–	–
	5	–	–	–	–

4862

		1	4	9	13
8661	11	–	–	–	–
	5	–	–	–	–

9323

		1	4	7	9
8661	11	–	–	–	–
	5	–	–	–	–

8594

		9	18	22	42
8661	11	–	–	–	–
	5	–	–	–	–

5124

		1	8	9	10
8661	11	–	–	–	–
	5	–	–	–	–

Appendix H (continued).

3879

		15	16	17	20
8661	11	–	–	–	–
	5	–	–	–	–

7156

		14			
8661	11	+++	+++	+++	+++
	5	+++	+++	+++	+++

v153

		4	8	11	15
8661	11	+++	+++	+++	+++
	5	+++	+++	+++	+++

pbm 772

		11	14		
8661	11	+++	+++	+++	+++
	5	+++	+++	+++	+++

9305

		8	10	16	17
3488	2	+++			+++
	7		+++	+++	
	11		+++	+++	
	18	+++			+++

9315

		3	4	17	18
3488	2	+++			+++
	7		+++	+++	
	11		+++	+++	
	18	+++			+++

4383

		4	8	12	20
3488	2	+++			+++
	7		+++	+++	
	11		+++	+++	
	18	+++			+++

3822 et

		2	4	7	12
3488	2	+++			+++
	7		+++	+++	
	11		+++	+++	
	18	+++			+++

Appendix H (continued).

6273

3488		2	4	9	15
	2	+++			+++
	7		+++	+++	
	11		+++	+++	
	18	+++			+++

4862

3488		1	4	9	13
	2	+++			+++
	7		+++	+++	
	11		+++	+++	
	18	+++			+++

9323

3488		1	4	7	9
	2	+++			+++
	7		+++	+++	
	11		–	–	
	18	+++			+++

8594

3488		9	18	22	42
	2	–			–
	7		–	–	
	11		–	–	
	18	–			–

5124

3488		1	8	9	10
	2	–			–
	7		–	–	
	11		–	–	
	18	–			–

3879

3488		15	16	17	20
	2	+++			+++
	7		+++	+++	
	11		+++	+++	
	18	+++			+++

7156

3488		14
	2	–
	7	–
	11	–
	18	–

v153

3488		4	8	11	15
	2	–			–
	7		–	–	
	11		–	–	
	18	–			–

Appendix H (continued).

pbm
772

		11	14		
3488	2	–	–		
	7	–	–		
	11	–	–		
	18	–	–		

9315

		3	4	17	18
9305	8	+/+			+/+
	10		+/+	+/+	
	16		+/+	+/+	
	17	+/+			+/+

4383

		4	8	12	20
9305	8	+/+			+/+
	10		+/+	+/+	
	16		+/+	+/+	
	17	+/+			+/+

3822e
t

		2	4	7	12
9305	8	+/+			+/+
	10		+/+	+/+	
	16		+/+	+/+	
	17	+/+			+/+

6273

		2	4	9	15
9305	8	+/+			+/+
	10		+/+	+/+	
	16		+/+	+/+	
	17	+/+			+/+

4862

		1	4	9	13
9305	8	+/+			+/+
	10		+/+	+/+	
	16		+/+	+/+	
	17	+/+			+/+

9323

		1	4	7	9
9305	8	+/+			+/+
	10		+/+	+/+	
	16		+/+	+/+	
	17	+/+			+/+

8594

		9	18	22	42
9305	8	–			–
	10		–	–	
	16		–	–	
	17	–			–

Appendix H (continued).

5124

		1	8	9	10
9305	8	–			–
	10		–	–	
	16		–	–	
	17	–			–

3879

		15	16	17	20
9305	8	+++			+++
	10		+++	+++	
	16		+++	+++	
	17	+++			+++

7156

		14			
9305	8	–	–		
	10	–	–		
	16	–	–		
	17	–	–		

v153

		4	8	11	15
9305	8	–			–
	10		–	–	
	16		–	–	
	17	–			–

pbm 772

		11	14		
9305	8	+++	+++		
	10	+++	+++		
	16	+++	+++		
	17	+++	+++		

4383

		4	8	12	20
9315	3	+++			+++
	4		+++	+++	
	17		+++	+++	
	18	+++			+++

3822 et

		2	4	7	12
9315	3	+++			+++
	4		+++	+++	
	17		+++	+++	
	18	+++			+++

6273

		2	4	9	15
9315	3	+++			+++
	4		+++	+++	
	17		+++	+++	
	18	+++			+++

Appendix H (continued).

4862

9315		1	4	9	13
	3	$_{+}+^{+}$			$_{+}+^{+}$
	4		$_{+}+^{+}$	$_{+}+^{+}$	
	17		$_{+}+^{+}$	$_{+}+^{+}$	
	18	$_{+}+^{+}$			$_{+}+^{+}$

9323

9315		1	4	7	9
	3	$_{+}+^{+}$			$_{+}+^{+}$
	4		$_{+}+^{+}$	$_{+}+^{+}$	
	17		$_{+}+^{+}$	$_{+}+^{+}$	
	18	$_{+}+^{+}$			$_{+}+^{+}$

8594

9315		9	18	22	42
	3	$_{+}+^{+}$			$_{+}+^{+}$
	4		$_{+}+^{+}$	$_{+}+^{+}$	
	17		$_{+}+^{+}$	$_{+}+^{+}$	
	18	$_{+}+^{+}$			$_{+}+^{+}$

5124

9315		1	8	9	10
	3	$_{+}+^{+}$			$_{+}+^{+}$
	4		$_{+}+^{+}$	$_{+}+^{+}$	
	17		$_{+}+^{+}$	$_{+}+^{+}$	
	18	$_{+}+^{+}$			$_{+}+^{+}$

3879

9315		15	16	17	20
	3	$_{+}+^{+}$			$_{+}+^{+}$
	4		$_{+}+^{+}$	$_{+}+^{+}$	
	17		$_{+}+^{+}$	$_{+}+^{+}$	
	18	$_{+}+^{+}$			$_{+}+^{+}$

7156

9315		14
	3	$_{+}+^{+}$
	4	$_{+}+^{+}$
	17	$_{+}+^{+}$
	18	$_{+}+^{+}$

v153

9315		4	8	11	15
	3	$_{+}+^{+}$			$_{+}+^{+}$
	4		$_{+}+^{+}$	$_{+}+^{+}$	
	17		$_{+}+^{+}$	$_{+}+^{+}$	
	18	$_{+}+^{+}$			$_{+}+^{+}$

pbm 772

9315		11	14
	3	$_{+}+^{+}$	$_{+}+^{+}$
	4	$_{+}+^{+}$	$_{+}+^{+}$
	17	$_{+}+^{+}$	$_{+}+^{+}$
	18	$_{+}+^{+}$	$_{+}+^{+}$

Appendix H (continued).

pbm
772

		11	14		
7866	1	+++	+++	+++	+++
	7	+++	+++	+++	+++
	10	+++	+++	+++	+++
	11				

3822
et

		2	4	7	12
4383	4	+++			+++
	8		+++	+++	
	12		+++	+++	
	20	+++			+++

6273

		2	4	9	15
4383	4	+++			+++
	8		+++	+++	
	12		+++	+++	
	20	+++			+++

4862

		1	4	9	13
4383	4	+++			+++
	8		+++	+++	
	12		+++	+++	
	20	+++			+++

9323

		1	4	7	9
4383	4	+++			+++
	8		+++	+++	
	12		+++	+++	
	20	+++			+++

8594

		9	18	22	42
4383	4	+++			+++
	8		+++	+++	
	12		+++	+++	
	20	+++			+++

5124

		1	8	9	10
4383	4	+++			+++
	8		+++	+++	
	12		+++	+++	
	20	+++			+++

3879

		15	16	17	20
4383	4	+++			+++
	8		+++	+++	
	12		+++	+++	
	20	+++			+++

Appendix H (continued).

7156

		14			
4383	4	+++			
	8	+++			
	12	+++			
	20	+++			

v153

		4	8	11	15
4383	4	+++			+++
	8		+++	+++	
	12		+++	+++	
	20	+++			+++

pbm 772

		11	14		
4383	4	+++	+++		
	8	+++	+++		
	12	+++	+++		
	20	+++	+++		

6273

		2	4	9	156
3822et	2	+++			+++
	4		+++	+++	
	7		+++	+++	
	12	+++			+++

4862

		1	4	9	13
3822 et	2	+++			+++
	4		+++	+++	
	7		+++	+++	
	12	+++			+++

9323

		1	4	7	9
3822et	2	+++			+++
	4		+++	+++	
	7		+++	+++	
	12	+++			+++

8594

		9	18	22	42
3822 et	2	+++			+++
	4		+++	+++	
	7		+++	+++	
	12	+++			+++

5124

		1	8	9	10
3822et	2	+++			+++
	4		+++	+++	
	7		+++	+++	
	12	+++			+++

Appendix H (continued).

3879

		15	16	17	20
3822 et	2	+/+/+			+/+/+
	4		+/+/+	+/+/+	
	7		+/+/+	+/+/+	
	12	+/+/+			+/+/+

7156

		14			
3822et	2	–			
	4	–			
	7	–			
	12	–			

v153

		4	8	11	15
3822 et	2	–			–
	4		–	–	
	7		–	–	
	12	–			–

pbm 772

		11	14		
3862	14	+/+/+	+/+/+		
	18	+/+/+	+/+/+		
	19	+/+/+	+/+/+		
	20	+/+/+	+/+/+		

4862

		1	4	9	13
6273	2	+/+/+			+/+/+
	4		+/+/+	+/+/+	
	9		+/+/+	+/+/+	
	15	+/+/+			+/+/+

9323

		1	4	7	9
6273	2	+/+/+			+/+/+
	4		+/+/+	+/+/+	
	9		+/+/+	+/+/+	
	15	+/+/+			+/+/+

8594

		9	18	22	42
6273	2	–			–
	4		–	–	
	9		–	–	
	15	–			–

5124

		1	8	9	10
6273	2	–			–
	4		–	–	
	9		–	–	
	15	–			–

Appendix H (continued).

3879

6273	15	16	17	20
2	+++			+++
4		+++	+++	
9		+++	+++	
15	+++			+++

7156

6273	14
2	–
4	–
9	–
15	–

v153

6273	4	8	11	15
2	–			–
4		–	–	
9		–	–	
15	–			–

pbm
772

6273	11	14
2	–	–
4	–	–
9	–	–
15	–	–

9323

4862	1	4	7	9
1	+++			+++
4		+++	+++	
13		+++	+++	
19	+++			+++

8594

4862	9	18	22	42
1	–			–
4		–	–	
13		–	–	
19	–			–

5124

4862	1	8	9	10
1	–			–
4		–	–	
13		–	–	
19	–			–

3879

4862	15	16	17	20
1	+++			+++
4		+++	+++	
13		+++	+++	
19	+++			+++

Appendix H (continued).

7156

4862	14
1	–
4	–
13	–
19	–

v153

4862	4	8	11	15
1	–			–
4		–	–	
13		–	–	
19	–			–

pbm
772

4862	11	14
1	–	–
4	–	–
13	–	–
19	–	–

8594

9323	9	18	22	42
1	–			–
4		–	–	
7		–	–	
9	–			–

5124

9323	1	8	9	10
1	–			–
4		–	–	
7		–	–	
9	–			–

3879

9323	15	16	17	20
1	+++	+++	+++	+++
4	+++	+++	+++	+++
7	+++	+++	+++	+++
9	+++	+++	+++	+++

7156

9323	14
1	–
4	–
7	–
9	–

v153

9323	4	8	11	15
1	–			–
4		–	–	
7		–	–	
9	–			–

Appendix H (continued).

pbm
772

		11	14		
9323	1	–	–		
	4	–	–		
	7	–	–		
	9	–	–		

5124

		1	8	9	10
8594	9	+ + +			+ + +
	18		+ + +	+ + +	
	22		+ + +	+ + +	
	42	+ + +			+ + +

3879

		15	16	17	20
8594	9	–			–
	18		–	–	
	22		–	–	
	42	–			–

7156

		14
8594	9	–
	18	–
	22	–
	42	–

v153

		4	8	11	15
8594	9	–			–
	18		–	–	
	22		–	–	
	42	–			–

pbm
772

		11	14		
8594	9	+ + +	+ + +		
	18	+ + +	+ + +		
	22	+ + +	+ + +		
	42	+ + +	+ + +		

3879

		15	16	17	20
5124	1	–			–
	8		–	–	
	9		–	–	
	10	–			–

7156

		14
5124	1	–
	8	–
	9	–
	10	–

Appendix H (continued).

		v153 4	v153 8	v153 11	v153 15
5124	1	–			–
	8		–	–	
	9		–	–	
	10	–			–

		pbm 772 11	pbm 772 14		
5124	1	–	–		
	8	–	–		
	9	–	–		
	10	–	–		

		7156 14			
3879	15	–			
	16	–			
	17	–			
	20	–			

		v153 4	v153 8	v153 11	v153 15
3879	15	–			–
	16		–	–	
	17		–	–	
	20	–			–

		pbm 772 11	pbm 772 14		
3879	15	–	–		
	16	–	–		
	17	–	–		
	20	–	–		

		v153 4	v153 8	v153 11	v153 15
7156	14	$_{-}+^{+}$	$_{-}+^{+}$	$_{-}+^{+}$	$_{+}+^{-}$

		pbm 772 11	pbm 772 14		
7156	14	$_{-}+^{+}$	$_{+}+^{-}$	$_{-}+^{+}$	$_{+}+^{+}$

		pbm 772 11			
v153	4	$_{+}+^{+}$	$_{-}+^{+}$		
	8	$_{-}+^{+}$	$_{+}+^{+}$		
	11	$_{-}+^{+}$	$_{+}+^{-}$		
	15	$_{+}+^{-}$	$_{+}+^{+}$		

B. Summary figure of intercollection pairing experiments

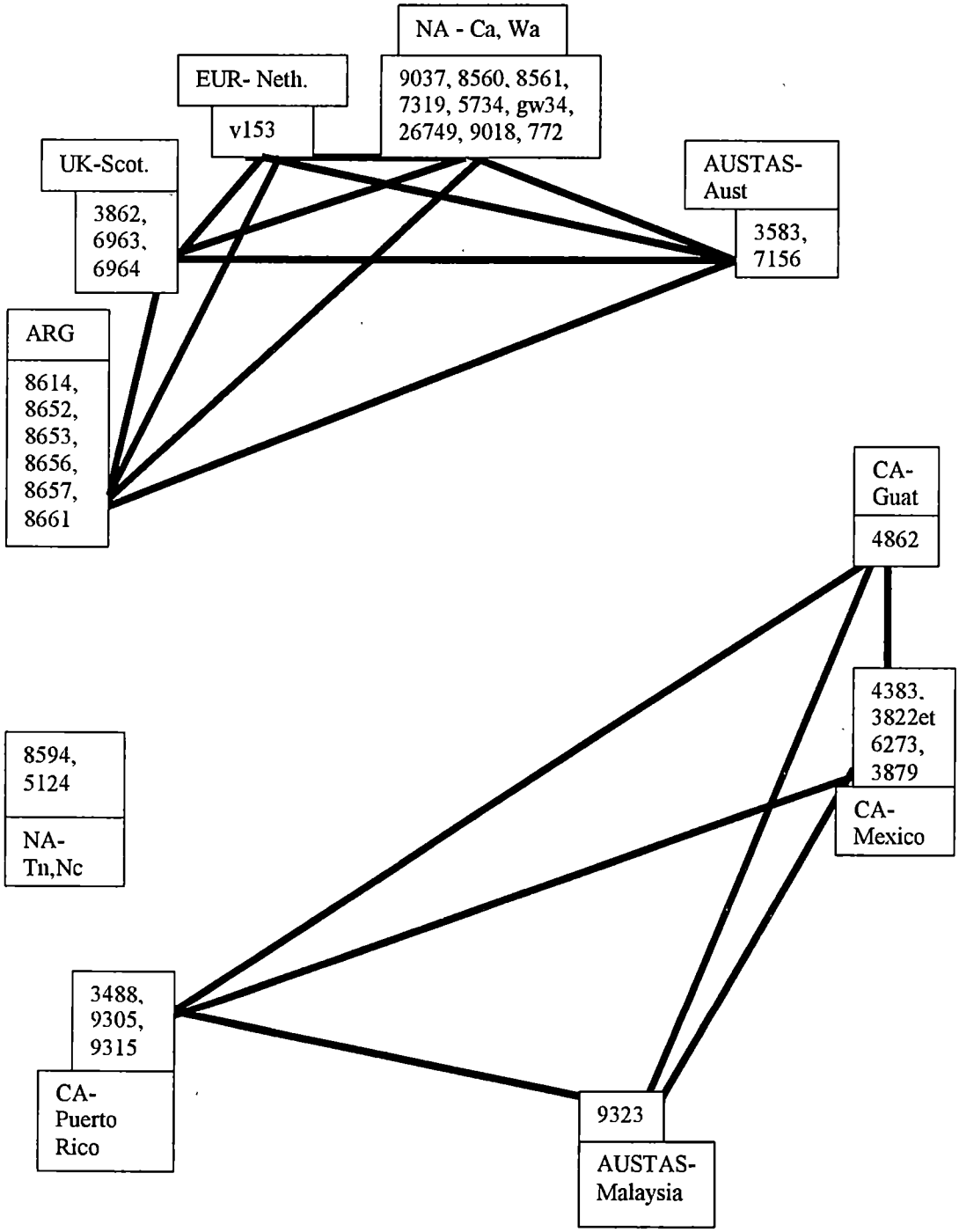
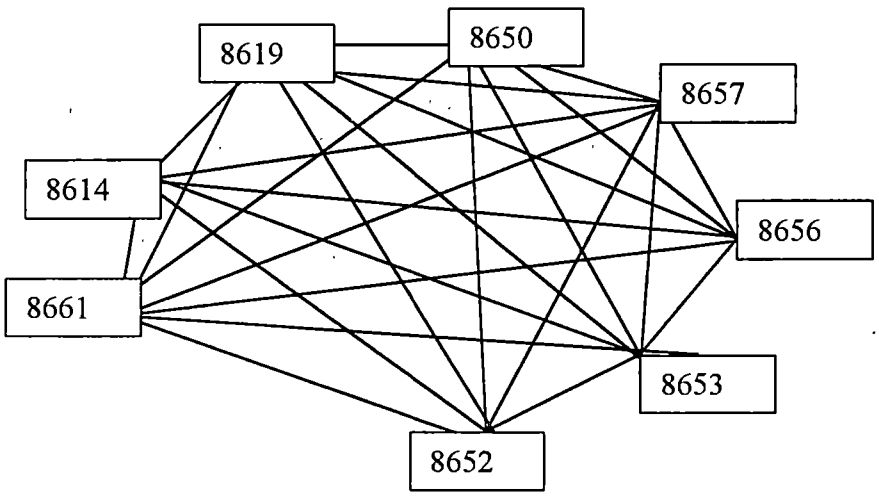
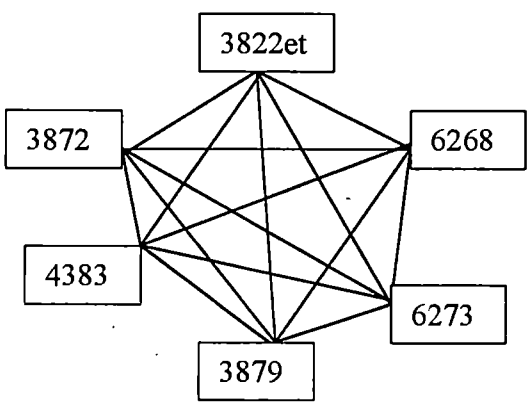


Figure 24. Summary figure of total intercollection crosses. n = 4-16, solid line = 90-100% intercompatibility. See Fig.1 for Locale Abbreviations. Isolates listed by field number. Isolates in box = 100% intercompatible.

C. Summary Figures of Multiple Collection Round-Robin Crosses.



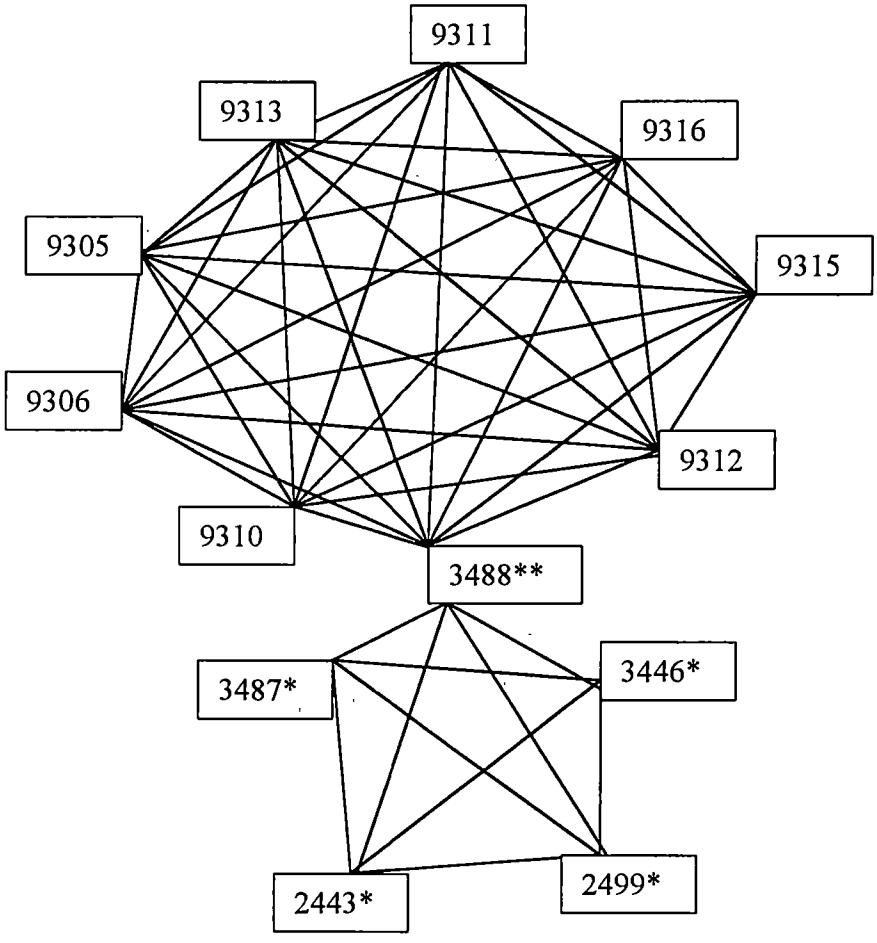
1) Argentina: *M. horizontalis*.n = 8, solid line = 100% compatibility. Dash-Dot line = 100% interINincompatibility.



2) Mexico: *M. alpiniae*. n= 4, Solid line = 100% compatibility. Dash-Dot line = 100% interINincompatibility.

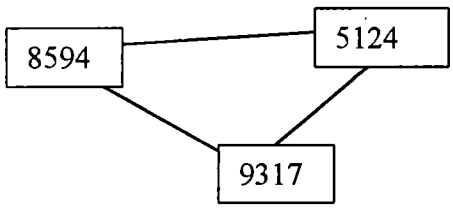
Figure 25. Summary figures of multiple-collection infraspecific crosses. Solid line = 100% compatibility. Dash-Dot line = 100% interINincompatibility.

Figure 25 (continued).



3) Puerto Rico: *M. alpiniae*. n = 4-8. * = Results from Petersen (1992a). Single-basidiospore isolates not available (dead) at time of this study. n = 4. [** = Singular collection with viable SBIs from Petersen, (1992a) study]. Solid line = 100% compatibility. Dash-Dot line = 100% interINincompatibility.

Figure 25 (continued).



4) Tennessee and North Carolina: *M. defraudatus*. n = 4, Solid line = 100% compatibility. Dash-Dot line = 100% interINincompatibility.

APPENDIX I: DNA AMPLIFICATION FINGERPRINTING DATA

A. Data Matrixes

Table 3. 125 polymorphic loci between 44 isolates of *Melanotus* species generated by 10 heptamer and octamer primers.

v153	8594	2443	2499	3487	3488	3583	3862	4383	5124	5734	grw34	6268	6273	7156	7319	8560	8561	8614	8619	8652	8653
1	0	1	1	1	1	1	0	0	1	0	0	0	0	1	1	0	0	0	0	0	1
0	0	1	1	1	1	0	1	0	0	0	0	1	1	0	1	0	0	0	0	1	1
1	0	0	0	1	1	0	0	1	0	1	1	1	0	1	1	0	1	1	0	0	0
1	0	0	0	0	0	1	1	1	1	0	0	0	1	1	1	1	1	1	0	1	1
0	1	1	1	0	1	1	0	1	0	0	0	1	1	0	0	1	1	0	0	1	0
1	0	0	0	1	1	1	1	0	0	0	1	0	1	1	1	0	0	1	1	1	1
1	0	0	0	0	1	1	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	1	1	0	1	1	1	1
0	1	1	1	1	1	0	0	1	0	0	0	0	1	1	1	0	0	0	0	0	0
1	0	1	1	1	1	1	1	1	0	0	1	1	1	0	1	1	1	0	0	0	0
0	0	0	0	1	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0
1	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	1	1	1	1	1	1
1	0	0	0	0	0	1	1	0	0	1	1	0	0	1	1	1	1	1	1	1	1
1	0	0	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	1	1	0	0	1	0	0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1	0
1	1	0	0	1	0	1	0	1	0	0	0	1	0	1	0	1	0	0	1	1	0
1	1	0	0	0	0	1	0	1	1	0	0	0	0	1	0	1	0	0	0	1	1
0	0	0	1	1	1	1	0	0	0	0	1	0	0	1	1	0	0	1	0	1	1
1	0	0	0	0	0	1	1	0	0	1	1	0	0	1	1	1	1	1	1	1	1
0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	9	0	0	0
0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	9	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	1	1	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	1	1	0	0	0	1
1	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	1	1	1	1	0	1
1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1
0	0	1	1	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
1	0	0	0	0	0	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1
0	1	1	1	1	0	0	0	1	0	0	0	1	1	0	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1
0	1	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
0	0	1	1	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
0	0	1	1	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Table 2 (continued).

v153	8594	2443	2499	3487	3488	3583	3862	4383	5124	5734	grw34	6268	6273	7156	7319	8560	8561	8614	8619	8652	8653
0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0	0	1	1	1	1
0	1	1	1	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0
0	0	1	1	1	1	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0
1	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	1	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	1	0	0	1	1	0	0	1	1	0	1	1	1	1	1
1	1	0	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	1	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	1	0	0	1	1	0	0	1	0	1	1	1	1	1	1
1	1	0	0	1	0	1	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0
1	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	1	0
0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	0	0	1	1	1	0	0	0	0	0	1	1	0	1	1	1	0	0
1	0	0	0	0	0	1	1	1	0	1	1	1	1	1	0	0	1	1	1	0	0
0	0	1	1	1	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0
1	0	1	1	0	0	1	1	0	1	1	0	0	0	1	1	1	1	1	1	1	1
1	0	0	1	1	0	1	0	1	0	1	1	1	0	1	1	1	1	0	0	0	0
1	0	0	0	1	1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1	0
0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0
1	0	0	1	0	0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1
0	1	1	1	0	0	1	0	1	1	0	0	0	0	1	1	0	0	0	1	0	0
0	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	1	1	1	1	1	1
0	0	0	0	1	0	1	1	1	0	1	1	0	0	1	0	0	0	1	1	1	1
1	0	0	0	0	0	1	1	0	0	1	1	0	0	1	1	1	1	1	1	1	1
0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
1	1	0	1	1	1	1	1	0	0	1	1	0	0	1	1	1	1	1	1	0	0
1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	0	0	1	0	0	0	1	1	0	0	1	1	1	1	1	1	1	1
0	0	1	1	1	1	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0
0	0	1	1	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0
0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
0	1	0	1	1	1	0	0	1	1	0	0	0	0	1	0	1	0	1	1	1	0
1	0	0	0	1	0	1	1	0	0	1	1	0	0	1	1	1	1	1	1	1	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
0	0	1	1	1	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0
0	1	1	1	0	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0
0	0	0	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0

Table 2 (continued).

v153	8594	2443	2499	3487	3488	3583	3862	4383	5124	5734	grw34	6268	6273	7156	7319	8560	8561	8614	8619	8652	8653
1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	0
1	0	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	0	0	1	1	1
0	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
0	0	1	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
0	0	0	0	1	0	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	1
1	0	0	0	0	0	1	1	0	0	1	1	0	0	1	1	1	1	1	1	1	0
0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	0	1	1	0	1	1	1	1	0	1	1	0	0	0	0	0
0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0
0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
0	1	1	1	1	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0
0	0	0	0	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
0	0	1	1	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
1	0	0	0	1	0	0	0	1	1	0	0	1	1	0	1	0	0	0	0	0	0
1	0	0	0	0	0	1	1	0	0	1	1	0	0	1	1	1	1	1	1	1	1
1	0	0	0	0	0	1	1	0	0	1	1	0	0	1	1	1	1	1	1	1	1
0	0	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	0	1	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1
0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1
0	0	1	1	1	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0
0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	1	0	0	0	0

Table 2 (continued).

8656	8657	8661	9018	9037	9305	9306	9310	9311	9312	9313	9315	9316	9317	9323	6964	3822et	3872	3879	3446	4862	772
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	1	0	0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	0	0	0	0	1	1	0
0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	1	1	1	1	1	0
0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
1	0	1	0	1	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	0	0
0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	1	1
0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1	1	0	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1	1	1	1	1
1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0
1	1	1	1	1	0	0	0	1	0	1	0	1	0	0	0	0	0	0	1	1	0
0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0
0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1
0	0	0	0	0	0	1	1	0	1	1	0	0	0	1	0	0	1	1	1	1	0
0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1
0	0	0	0	0	1	0	1	1	1	1	0	1	1	0	0	1	0	0	0	1	0
0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0
0	0	0	0	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	0
0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	1	1	1	1	1	0	0	1	0	0	0	0	1	0	1	0
0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	1	1	1	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1

Table 2 (continued).

8656	8657	8661	9018	9037	9305	9306	9310	9311	9312	9313	9315	9316	9317	9323	6964	3822et	3872	3879	3446	4862	772
0	1	0	0	0	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	1	0
0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	1
0	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	1
0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0
1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1
1	1	0	0	1	0	0	1	1	0	0	1	0	0	1	1	1	1	1	1	0	1
0	0	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1
1	0	1	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	1	0
1	0	1	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1
1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	1	1	0
0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	1	1	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
0	0	0	1	1	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0
0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1	1	1	1	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1
0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1	0
0	0	0	0	0	0	1	0	1	1	1	1	1	0	1	0	1	0	1	1	1	0
0	0	0	0	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0
0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0
1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	0
0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0
0	0	0	0	0	0	0	1	1	0	1	0	0	1	0	1	0	0	1	0	1	0
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1	0
0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	0	1	1	1
0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	0

Table 2 (continued).

8656	8657	8661	9018	9037	9305	9306	9310	9311	9312	9313	9315	9316	9317	9323	6964	3822et	3872	3879	3446	4862	772
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0
0	0	0	0	0	1	0	0	1	0	0	0	1	0	1	0	1	1	1	1	1	0
0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1	1	1	1	0
0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	1	0	0	0	0	1
0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	0
1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1
1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1
0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0
0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
1	1	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
0	0	0	0	0	0	0	0	1	1	1	1	0	1	0	0	1	1	1	1	1	0
0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

VITA

A. David Sime was born in Connecticut in 1967. He gradutated from New Fairfield High School in 1985. He attended Keene State University, Keene, New Hampshire where he was awarded the Bachelor of Arts in Biology in December, 1989. While in attendence at Keene State University he spent a semester abroad, studying Field Biology in Kenya, East Africa.

In January, 1992, David enrolled at Humboldt State University, Humboldt, California to study with Dr. David L. Largent. During this time he held a research assistant ship with the California Department of Forestry and Fire Protection, supervising a research project on the biology of mycorrhizal fungi. David also supervised several undergraduate senior projects for the Humboldt State University Mycological Laboratory, and worked on ancillary mycorrhizal projects at the Lanphere Christian Dunes Nature Conservancy. While at Humboldt David also acted as a fungal identification expert in several public settings. He received the Master of Arts in Biology in May, 1995.

In September, 1996 David entered The Graduate School of the University of Tennessee, Knoxville, to study with Dr. R. H. Petersen. He received the Doctor of Philosophy with a major in Botany in December, 2000. While in attendence at UT he undertook extensive field work in Argentina, Puerto Rico, and the southeastern United States. He has participated in professional meetings of the Mycological Society of America, and the XVI International Botanical Congress. In December of 2000 David

assumed the position of Mycological Analyst at the Environmental Microbiology Laboratory, Inc. in San Francisco, California. David is married to Stephanie Ann Stika, who shares an avid interest in mycology and has a Bachelor of Science in Ornamental Horticulture and Land Design from the University of Tennessee, Knoxville. They have two dogs, Willow and Frodo, who aid in all mycological forays.