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Possible sources of genetic resistance in oil palm (*Elaeis guineensis* Jacq.) to basal stem rot caused by *Ganoderma boninense* – prospects for future breeding

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Abstract

Oil palm estates in southeast Asia suffer from substantial losses due to basal stem rot caused by *Ganoderma boninense*. Field observations have been carried out in North Sumatra, Indonesia, on a series of planting materials of known origin. Differences in susceptibility to the disease have been detected within the two *Elaeis* species, *guineensis* and *oleifera*. Within *Elaeis guineensis*, material of Deli origin is highly susceptible compared to material of African origin. It is also possible to detect differences in reaction between parents and between crosses within a given origin. The variability of resistance to basal stem rot within the same cross is also illustrated by the diverse responses of clones derived from palms of the same origin. The prospects opened up by these results are discussed, and the importance of performing an early selection test is highlighted.

Key words: breeding, *Ganoderma*, Indonesia, oil palm, resistance

Introduction

Oil palm monocultures are a recent development. Indeed, whilst traditional oil palm cultivation in Africa goes back to ancient times, the areas devoted to more intensive cultivation have increased substantially worldwide since the 1960s [1]. In Asia, these areas have increased from under 200,000 ha in the 1960s to more than 6.5 million ha today, and Asia is now the world's leading production zone, and accounts for almost 90% of palm oil production. The two largest producing countries in the zone are Malaysia and Indonesia. One of the main obstacles to oil palm (*Elaeis guineensis*) cultivation in Asia is stem rot diseases caused by *Ganoderma boninense*, which is commonly known as 'Basal Stem Rot' (BSR), when the bottom of the stem is affected and 'Upper Stem Rot' when rot occurs higher up the stem. These rots are very economically important and between 30% and 70% of palms are often lost to stem rots by the end of a planting cycle [2]. The damage caused is becoming increasingly serious and occurs increasingly early from one planting cycle to the next.

Many cultural techniques and practices have been developed to try and control stem rots [3]. At best, these can slow down pathogen development, but there is still no effective and economically acceptable way of controlling the disease.

However, if genetic control of the disease were possible, it would be a major advance. In order to achieve this, it is necessary to determine whether any sources of genetic resistance exist in *E. guineensis*, of African origin, and in the related species *E. oleifera*, which originates from central and South America. In 2001, de Franqueville et al. [4]

presented a set of results indicating that there were differences in susceptibility to BSR within oil palm genetic resources.

Breeding trials have been set up as part of long-standing collaboration between Cirad and the P.T. Socfindo company. The trials are being conducted at Bangun Bandar Estate (North Sumatra), where BSR incidence is sufficient to detect significant differences in performance between planting materials. This estate, like the oldest estates in Indonesia or Malaysia, has been replanted two to four times, and it can be assumed that disease development there will be reasonably indicative of the situation that will prevail when more recent estates are renewed.

The purpose of this article is to consolidate the results obtained in 2001 [4] and focus on inter-specific differences between *E. guineensis* and *E. oleifera*, differences between origins within the species *E. guineensis,* and differences within single origins. If the latter type of differences exist, they should be reflected in differences in performance between individuals, and may lead to differences between individual crosses or clones.

Material and methods

Trials and planting material

At the outset, the trials planted at Bangun Bandar, the most significant of which are presented here, were intended for genetic studies. They were planting material comparative trials for varietal improvement programmes or clone comparative trials, planted in a statistical design, or parental material planted without a statistical design. The mating designs, like the statistical designs, are therefore not perfectly adapted to a disease development study. Nevertheless, they have provided significant results. The main characteristics of the trials are listed in Table 1.

Genetic origins of planting material

Various planting materials of *E. guineensis* and *E. oleifera* from different genetic origins were used in the trials.

Table 1. List of trials planted at Bangun Bandar and their main characteristics

Trial number	Planting year	Planting cycle (generation)	Number of crosses or clones	Statistical design: If Fisher blocks (FB): obj.*rep*no of palms	Comments
Material derived from crosses					
BB GT 1 A	1974	1	16	FB 16*5*12	Various first cycle crosses
BB GT 1 C	1974	1	11	FB 11*6*12	*E. guineensis* and *E. oleifera*
BB GT 1 D	1975	1	6	FB 6*6*16	Various first cycle crosses
BB GT 1 E	1976	1	6	FB 6*6*16	
BB GT 11 D	1981	3	4 categories	FB 4*6*50	First cycle commercial plt material
BB GT 12	1983	3	15	FB 15*8*10	Recombination plt material
BB GT 17	1984	3	7 categories	FB 7*8*640	First cycle commercial plt material
BB GT 21	1991	2	18	FB 18*5*16	Second cycle Deli × Yangambi
BB GT 25	1986	3	12	FB 12*6*12	(Angola or Deli × Ang.) × La Mé
BB GT 28	1986	3	15	FB 15*5*15	First cycle best crosses from LM
Clonal trials					
BB CL 1 ou Demplot	1986	3	6	In rows	6 clones
BB CL 2	1986	2	5	FB 5*6*20	4 clones, 1 cross
BB CL 3	1987	2	10	FB 10*6*16	9 clones, 1 cross
BB CL 4	1989	3	9	FB 9*6*16	7 clones, 2 crosses
BB CL 5	1989	3	11	FB 11*6*16	9 clones, 2 crosses
BB CL 6	1991	2	12	FB 12*6*16	11 clones, 1 cross
BB CL 7	1993	2	17	FB 17*3*16	17 clones
Parental material					
Block 60	1974	1		In rows	Group A (Deli) and B (LM , YA)

E. guineensis *material*

Seven different lines from five different origins were used. These were: two genetically quite similar populations, Dabou and Socfin, of the Deli material developed in Indonesia and Malaysia; two populations, Salazar and Novo Redondo, of Angolan origin; material from the Congo basin, Yangambi, selected either by Socfindo or by the La Mé Station (CNRA, Côte d'Ivoire); material from Côte d'Ivoire, La Mé, primarily represented by parents from the BRT 10 field: and parents from Nigeria selected by NIFOR (Nigerian Institute for Oil Palm Research). The *E. guineensis* materials were all previously described by Cochard et al. [5].

E. oleifera *material*

E. oleifera was represented by a single population of Mangenot [6].

Field observation methods

Observations were carried out twice a year, using a seven-step scoring scale. Measurements have been taken systematically since 1996 in all the trials, but are not always available with the same precision for earlier years. However, in this study the results shown are based on percentages of plants affected or killed by *Ganoderma*.

Differences between the percentages of diseased plants observed in the different materials at a given moment were tested by an analysis of variance with a generalised linear model. The model used considered that the number of affected palms followed a binomial distribution whose p parameter was linked to the factor by a logit transformation $[X = \log(p/1-p)]$. The correlation of affected palms within an elementary plot was represented by a random plot effect.

In order to compare the materials planted in the most important trials with each other, an index was developed for the different treatments, similar to that used to interpret vascular wilt resistance tests in West Africa [7, 8]. By definition, the mean of a trial corresponded to an index of 100. The index attributed to each tested unit was the ratio of the percentage of plants affected by *Ganoderma* to the trial mean multiplied by 100. An index below 100 indicated that the cross or clone was less affected than the trial mean, and conversely for an index over 100. A low index characterised resistant material, whilst a high index reflected substantial susceptibility.

Results

Interspecific differences

Trial BB GT 1C was planted in 1974 to compare *E. guineensis* × *E. guineensis* crosses with *E. guineensis* × *E. oleifera* crosses. In this trial, the first cases of BSR caused by *Ganoderma* occurred 20 years after planting (1994) in a first oil palm planting cycle after rubber. Eight years later, in 2002, 31% of the plants had developed the disease. The results expressed as cumulative percentages, are shown in Table 2. The differences were very highly significant between the two types of crosses and the *E. oleifera* origin. The Mangenot line appeared to provide a source of resistance to the disease.

Table 2. Trial BBGT 1C, comparison of the BSR percentage between crosses depending on cross type

Crosses	Cross type	Percentage of plants affected by BSR (end of 2002)	Statistical group (Student)
BB 71 D × BB 5 P	*E. guineensis* × *E. guineensis*	65.7	a
BB 71 D × PO 1878 T	*E. guineensis* × *E. guineensis*	61.2	a
BB 70 D × LM 2060 P	*E. guineensis* × *E. guineensis*	53.2	a
BB 70 D × BB 13 P	*E. guineensis* × *E. guineensis*	47.0	a
BB 70 D × LM 238 T	*E. guineensis* × *E. guineensis*	32.9	a
ME 7 D × LM 312 P	*E. guineensis* × *E. oleifera* "Mangenot"	26.2	b
ME 7 D × LM 327 P	*E. guineensis* × *E. oleifera* "Mangenot"	21.5	b
ME 5 D × LM 2234 P	*E. guineensis* × *E. oleifera* "Mangenot"	18.5	b
ME 1 D × LM 319 P	*E. guineensis* × *E. oleifera* "Mangenot"	17.9	b
ME 9 D × LM 2466 P	*E. guineensis* × *E. oleifera* "Mangenot"	13.0	b
ME 9 D × LM 314 P	*E. guineensis* × *E. oleifera* "Mangenot"	12.7	b

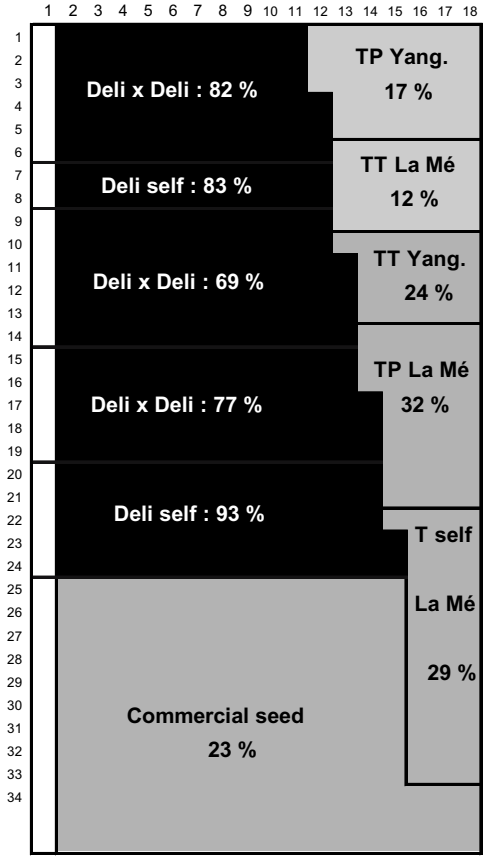

Figure 1. Block 60: BSR rate depending on the location of the parental material in the field.

Table 3. Observation of BSR incidence in Socfindo commercial plantations in 1970

Estate	Block	Planting year	Type of material	% BSR
Mata Pao	2	1958	Deli × Deli	74
	3	1955	Deli × Deli	61
	4	1955	Deli × Deli	60
	5	1955	Deli × Deli	73
	13	1958	**Deli × Yangambi**	**16**
	18	1958	**Deli × Yangambi**	**25**
Tanah Gambus	32	1957	Deli × Deli	33
	33	1957	Deli × Deli	24
	47	1957	**Deli × Yangambi**	**13**
	53	1957	**Deli × Yangambi**	**12**

Source: Akbar et al. [9]

Differences between origins within E. guineensis

The material of Deli origin showed high susceptibility to BSR, and this was much greater than that expressed by the other *E. guineensis* origins. Two examples were particularly noteworthy. The first was a study of parental material planted in Block 60 at the Bangun Bandar station (Figure 1), reported by de Franqueville et al. [4]. These observations confirmed those reported by Akbar et al. as early as 1971 [9] in other P.T. Socfindo estates (Mata Pao and Tanah Gambus) that are shown in Table 3.

However, in view of the planting designs, it has not been possible to determine differences in susceptibility between the African origins.

Differences within origins

It is possible to show that significant differences exist in susceptibility to *Ganoderma* within a given genetic origin. For instance, variations can be identified within Deli materials, the Angola material and the material of La Mé origin.

Deli origin. Two trials (BB GT 11 D and BB GT 17) compared first selection cycle hybrid categories[1], of the Deli × La Mé or Deli × Yangambi type. Six of these categories were obtained by selfing parent LM 2 T, which is used as a tester with the Deli origin. Very highly significant differences were observed (Table 4).

Deli materials derived from parent DA 118 D were more susceptible to the disease than a group comprising Deli materials derived from LM 404 D and DA 115 D. The DA 5 D × DA 3 D cross was similar to LM 404 D in trial BB GT 11 D. It would therefore appear that Deli materials derived from DA 10 D, were the least susceptible of this origin. This observation is corroborated by the performance of cross DA 10 D × LM 2 T.

In trial BB GT 11 D, category C1401, which represented the cross DA 10 D × LM 2 T, was the least affected by *Ganoderma* and had an index of 55, and in this trial the parent DA 10 D proved to be better than LM 404 D or the DA 5 D × DA 3 D cross. Cross DA 10 D × LM 2 T itself, and not its reproduction through a category, has been planted in several trials at the Bangun Bandar station. As soon as disease pressure increases it always performs better in respect of G*anoderma* resistance than the mean of the material to which it has been compared (Table 5).

Table 4. Observation of BSR incidence in two trials (BBGT 11D and BBGT 17) comparing commercial planting materials grouped in categories

Trial	Category	Genetic origin of Deli dura parents	Genetic origin of parents: La Mé (LM) or Yangambi (Ybi)	% BSR (Index)	Statistical group (Student)
BB GT 11 D (1981 planting)	C 33 04	DA 3 D × PO 498D	LM 451 T Self (LM)	53.1 (131)	a
	C 25 01	DA 3 D × D5D	LM 2 T Self (LM)	43.6 (108)	a
	C 15 01	LM 404 D Self	LM 2 T Self (LM)	42.7 (106)	a
	C 14 01	DA 10 D Self	LM 2 T Self (LM)	22.3 (55)	b
BB GT 17 (1984 planting)	No code	(4007)	T 377 (Ybi)	35.4 (128)	a
	C 11 01	DA 118 D Self	LM 2 T Self (LM)	34.7 (126)	a
	No code	(4004)	T 328 (Ybi)	28.1 (101)	b
	C 23 01	LM 269 D × DA 115 D	LM 2 T Self (LM)	27.9 (101)	b
	C 10 01	DA 115 D Self	LM 2 T Self (LM)	20.7 (75)	c
	C 15 01	LM 404 D Self	LM 2 T Self (LM)	19.2 (69)	c

Table 5. Average performance of cross DA 10 D × LM 2 T in the trials at Bangun Bandar

Trial	Average BSR % in the trial (end of 2002)	Average BSR % in DA 10 D × LM 2 T (end of 2002)	Index
BBCL 2	49.4	25.9	52
BBCL 3	30.0	18.1	60
BBGT 1A[a]	28.5 (in 1998)	12.0 (in 1998)	42
BBGT 28	15.0	12.4	82

[a] Trial ended in 1998.

Angola origin. Trial BB GT 25, planted in 1986 in a third planting cycle, showed differences within the Angola origin between two parents, one derived from Salazar (TS 2274), the other from Novo Redondo (TNR 115). The latter in particular appeared to transmit lower susceptibility, and its progeny performed at least as well as cross DA 10 D × LM 2 T (Table 6).

La Mé origin. The differences in susceptibility of La Mé material were less marked, although some general trends could be identified. LM 10 T appeared to transmit greater susceptibility than LM 2 T. Crosses involving these two parents have been planted in trials BB GT 28 and BB GT 1A, and an abstract of the latest results from these is given in Table 7. This trend however requires confirmation, particularly as the 'Deli' effect is very pronounced and highly significant: DA 8 D, like LM 269 D, transmited high susceptibility, unlike DA 10 D or LM 404 D.

Table 6. Average performance of two Angola origins (TS 2274 and TNR 155) in trial BBGT25 at Bangun Bandar

Treatment	Genetic origin ot the Deli Dura parents	Genetic origin of the Pisifera parents	Average BSR % (Indice)	Statistical group (Student)
05-LM 12433	TS 2274 × LM 630 D	LM 2 T × LM 5 T	17.8 (276)	a
07-LM 11406	TS 2274 × LM 630 D	LM 5 T × LM 10 T	12.4 (193)	a b
09-LM 11337	TS 2274 × LM 630 D	LM 2 T × LM 5 T	12.4 (193)	a b
08-LM 11720	TS 2274 × LM 630 D	LM 5 T Self	10.0 (155)	a b c
03-LM 12273	TNR 115 × LM 630 D	LM 2 T × LM 5 T	8.2 (127)	a b c
01-LM 12649	DA 10 D (itself)	LM 2 T (itself)	8.2 (127)	a b c
06-LM 12231	TS 2274 × LM 630 D	LM 10 T Self	8.0 (123)	a b c
02-LM 12283	TNR 115 × LM 630 D	LM 5 T Self	4.1 (64)	b c
10-LM 12281	TNR 115 Self	LM 2 T × LM 5 T	4.0 (56)	b c
11-LM 12334	TNR 115 Self	LM 10 T Self	2.8 (43)	c
12-LM 11440	TNR 115 Self	LM 2 T Self	2.7 (42)	c
04-LM 12293	TNR 115 × LM 630 D	LM 5 T × LM 10 T	0.0 (0)	c

Table 7. Performance of LM 2 T, LM 5 T and LM 10 T in crosses in trials BBGT 1 A (in 1998) and BBGT 28 (in 2002). Results expressed as an index

	LM 2 T	LM 5 T	LM 10 T
DA 8 D			193, 265 [a]
DA 10 D	83, 42[a]	82	56
DA 118 D		123[a]	
LM 269 D	129, 137[a]	109	141
LM 404 D	43		92

[a] BB GT 1 A.

Parental material

It has not always been possible to compare parents with each other, but a few repeatedly showed similar performances that are worth reporting. Table 8 details four parents that are less susceptible to BSR than the mean. Three of these were of La Mé 'BRT 10' origin: LM 7 T, LM 311 P (derived from LM 2 T), LM 3953 T (derived from LM 5 T Self) and the fourth was derived from Yangambi selections carried out at La Mé (LM 718 T).

Performance of crosses or clones

Differences in the performance of parents with respect to *Ganoderma* infection were also found in crosses carried out between those parents. The most susceptible clones were usually derived from susceptible crosses, whilst clones derived from crosses that had only been slightly affected by BSR were usually barely affected themselves. For example, the four clones derived from susceptible cross LM 10 T × DA 8 D were all susceptible and clone SOC 0903 was very clearly susceptible, however the performance of clone SOC 0901 needs to be confirmed. Conversely, two clones, SOC 1502 and 1503, derived from cross BB 91 D × LM 311 P, gave low indexes (Table 9). Full data on the performance of these clones have been reported by de Franqueville et al. [4].

Table 8. Performance of parents LM 7 T, LM 311 P, LM 3953 T and LM 718 T in the trials planted at Bangun Bandar

Cross	Trial	Average BSR %in the trial	Index
LM 738 D × LM 7 T	BB GT 12	55.3	70
LM 268 D × LM 7 T	BB GT 1A	28.5	75
BB 179 D × LM 7 T	BB GT 1E	45.6	59
LM 269 D × LM 311 P	BB GT 1A	28.5	83
LM 404 D × LM 311 P	BB GT 1A	28.5	58
BB 91 D × LM 311 P	BB GT 1D	58.8	88
Four dura × LM 311 P	BB GT 24	9.6	43
LM 4060 D × LM 3953 T	BB GT 12	55.3	77
LM 4063 D × LM 3953 T	BB GT 12	55.3	72
LM 4067 D × LM 3953 T	BB GT 12	55.3	52
LM 404 D × LM 718 T	BB GT 1A	28.5	49
DA 10 D × LM 718 T	BB GT 28	15.0	89
LM 269 D × LM718T	BB GT 28	15.0	159
LM 269 D × LM718T	BB GT 28	15.0	131
DA 8 D × LM718T	BB GT 28	15.0	77

Discussion

Sources of resistance

The source of resistance to *Ganoderma* infection obtained from the Mangenot origin, in *E oleifera*, is not sufficient to support the idea of a general difference in susceptibility between the two species, *E. guineensis* and *E. oleifera*. That hypothesis will need to be confirmed by further crosses with

Table 9. Performance of some crosses in relation to BSR, and of clones derived from those crosses

Cross	Comments on the cross	Clones derivedfrom the cross	Indexes obtained by the clones
LM 10 T × DA 8 D	One of the clearly highly susceptible crosses	LMC 009	170
	(Indexes obtained:	SOC 0901	51, 153
	265 and 193)	SOC 0902	183,
		SOC 0903	210, 267, 175
BB 91 D × LM 311 P	LM 311 P transmits a good performance	SOC 1502	67
		SOC 1503	39, 23
LM 404 D × LM 718 T	LM 404 D and LM 718 T displays a satisfactory performance	SOC0403	100, 87, 91

material from other origins. Elsewhere in this volume Sankaran et al. [11] have highlighted strong differences in susceptibility to *Ganoderma* between the two species *Acacia mangium* and *A. auriculoformis*. Idris et al. [12] have also shown that other lines of *E. oleifera*, originating from Honduras, Panama and Colombia have similar susceptibility levels to the average level of susceptibility detected in *E. guineensis*.

The high susceptibility of the Deli material within *E. guineensis* has been largely confirmed [4, 9, 12, 13], and this clearly stands out from all the other so-called African origins (Angola, Côte d'Ivoire, Congo). This result will probably require geneticists to reconsider their genetic improvement programmes, in so far as virtually all seeds marketed worldwide are 50% Deli. New guidelines should tend to reduce the use of Deli material, or at least take advantage of the differences in susceptibility observed within it. The identification of further Deli parents with a lower susceptibility, such as DA 10 D, is a priority. The systematic observation of breeding programmes at research stations, such as the one belonging to P.T. Socfindo, at Bangun Bandar, that includes 70,000 palms, should provide much more information.

Given the biology of the pathogen, particularly the way it reproduces and its variability [14, 15], it would be advisable to seek partial resistance [16]. Between- and within-origin differences reported in this article, or by Idris et al. [12] and Purba et al. [17], could be exploited for that purpose. In the short term, an initial step will be to eliminate the strongest sources of susceptibility as much as possible from planting material.

There is no *Ganoderma*-free variety, and an all-or-nothing type reaction has not been observed even in clones. In environments where the material is highly concentrated in small areas, as is the case in a field trial, the percentage of affected plants remains high, even among the best progenies. An initial objective would be to attempt to limit losses to 15–20% by the end of a planting cycle, a threshold below which losses are generally not economically significant. BSR incidence also needs to be managed by integrated control.

Development of early tests

Differences in susceptibility were found between and within origins, and even within families themselves. This may encourage the development of a detection tool that enables such differences to be found as early as possible. Coherence between early results and those found in the field is a prerequisite, and it is now possible to take this into account, using the range of susceptibility that has been identified. The identification of sources of resistance or susceptibility is coherent throughout the different trials, and among the different authors, and that coherence is not affected by the order of the planting cycle. It is therefore now reasonable to put forward the hypothesis that a performance range will not necessarily be dependent upon external factors, be they biotic or abiotic. The ultimate goal of an early detection tool would be to assess as many progenies or origins as possible, as occurred for the methods used for vascular wilt in West Africa [18].

Most of the work undertaken to date has focused on inoculation methods, without reference to the planting material. However, the results obtained by Idris et al. [12] who used a range of planting materials with a very wide genetic base, are encouraging, in so far as they revealed an extended range of susceptibility that generally agreed with results observed in the field in Indonesia (the susceptibility of the Deli material, and the good performance of the African material). However, some important points need to be improved. The duration of the susceptibility/resistance testing, which is partly linked to pathogen biology, needs to be as short as possible and the procedure needs to enable the evaluation of a large number of origins.

The trials described in this article have been set up in first, second or third planting cycle zones. The spread of the disease was observed throughout the first generation, and has been observed for 25 years in the second generation and 22 years in the third generation. In no case has any notable acceleration in disease development been seen. BSR begins on younger palms and often leads to a larger percentage of affected palms by the end of the generation, but a situation such as that found with bud rot in Latin America, notably in Ecuador [19], where a linear phase is followed by an exponential phase once a certain percentage of palms have been affected, is not seen. However, as not all other things are equal, the kinetics observed need to be interpreted with caution.

In addition to providing information on genetic resistance, systematic observation of the 70,000

palms in the genetic trials on the P.T. Socfindo estates should provide information of an epidemiological nature and also on how planted palms are infected, and should enable a better assessment to be made of disease symptoms and how they develop.

Notes

[1] A first cycle hybrid category corresponds to all the crosses with the same grandparents. Depending on whether or not there was selfing, there will be 2, 3 or 4 grandparents. For example, two widely distributed hybrid categories are 'C1401' (dura of DA 10 D self crossed with pisiferas of LM 2 T self) and ''C2501'' (dura of (DA 5 D × DA 3 D) self crossed with pisiferas of LM 2 T self. C1401 is a reproduction of cross DA 10 D × LM 2 T [10].

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