THE EVALUATION OF HEMP (*Cannabis sativa* L.) AS A NON-WOOD SOURCE OF PAPER PULP

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INTRODUCTION

A study of non-wood paper pulp production in the Netherlands by means of hemp (*Cannabis sativa* L.) is presently in its final stage. In the context of this comprehensive study and prior to the breeding of improved cultivars, a germplasm collection (de Meijer & van Soest, 1992), covering the variation within the genus *Cannabis* has been evaluated in various experimental set-ups. This paper reports on the observed variation for, and relations between the most relevant agronomic traits. Conclusions will be presented with reference to breeding prospects.

PHENOLOGICAL DEVELOPMENT IN RELATION TO STEM PRODUCTION

The economic yield of hemp in the present project was defined as the yield of stem dry matter, including bark as well as woody core. Collection evaluation by means of the direct assessment of stem dry matter production is rather problematic. Phenological development was therefore investigated, as an indicator for potential stem production. Large variation was found for phenological development. At sowing date 1 April, the dates of anthesis ranged from 10 may to 25 September. The phenological pattern of accessions was associated with their latitude of origin (adaptation) (Figure 1). Accessions adapted to the Netherlands (52° latitude) started flowering at day 175 (25 June). Introduced accessions from higher latitude flowered earlier, those from lower latitude later.

Day of anthesis was strongly related with stem yield (Figure 2). The latest flowering fibre hemp landraces exceeded byfar

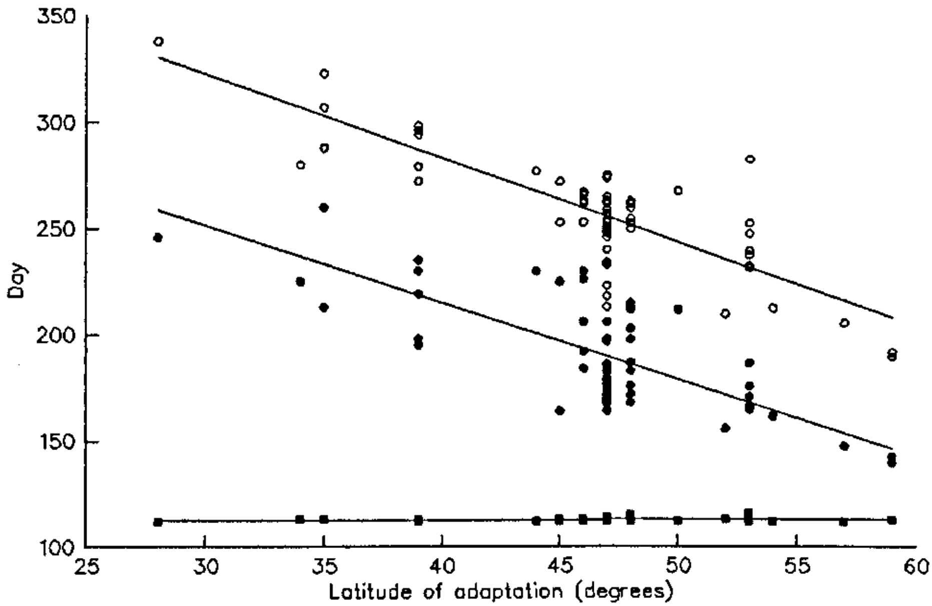

Figure 1: Day nr. of seedling emergence (squares), anthesis (solid circles) and seed maturity (open circles) in 1990 in relation to the latitude of adaptation.

the standard fibre cultivars in stem yield.

A desired phenological pattern of *Cannabis* populations can most easily be maintained by organizing seed reproduction outdoors at the appropriate latitude, thus avoiding genetic shift. Seed reproduction at low latitude for the purpose of stem production at high latitude is the most effective way of increasing stem yield.

Breeding can contribute to a better yield-potential by improving the persistency of cultivars. An additional opportunity is indicated by variation for the efficiency of utilizing the life cycle for stem dry matter accumulation among accessions with similar phenological patterns (Figure 2).

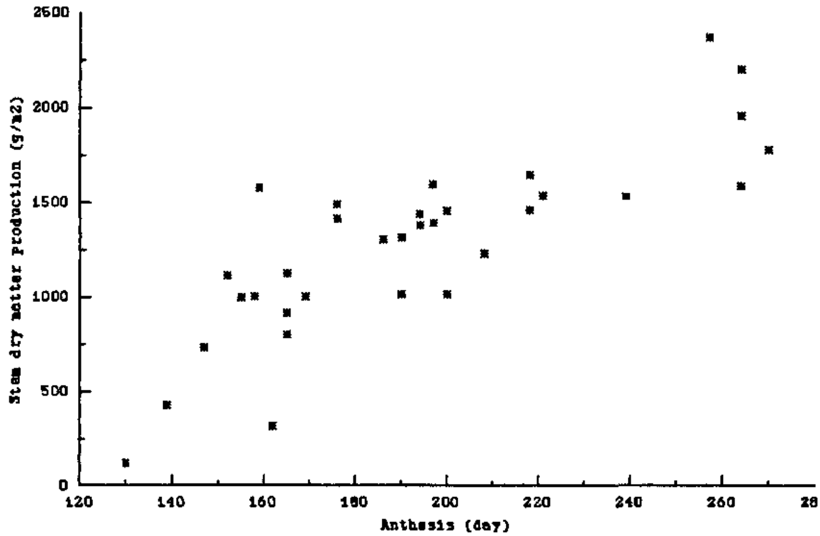

Figure 2: The relation between the day of anthesis and stem dry matter production. Data are means for 33 accessions which had a comparable plant density in the course of the life cycle.

Table 1. $LSD_{0.05}$, range of accession means and grand mean for various traits related to productivity in a 1993 field evaluation of 74 accessions. The initial plant density was 60 plants/m². Sowing date was 14 april, i.e. day nr. 104 in the year.

Traits	$LSD_{0.05}$	Range	Grand mean
Seedling emergence (day nr.)	0.75	112-115	112.7
Anthesis (day nr.)	18.5	130-270	205
Seed maturity (day nr.)	19.8	193-335	261
Stem length ♂ (cm)	45	102-410	303
Stem length ♀ (cm)	42	98-364	284
Final plant density (pl/m²)	18	10-60	37
Stem dry matter production (g/m²)	572	119-2443	1149

STEM QUALITY

Bark and woody core of *Cannabis* possess distinct properties. As the properties of the bark meet in general the requirements for manufacturing high quality pulp, the evaluation was for bark restricted to the assessment of the mass fractions in the stem of the entire tissue and its constituent primary and secondary bast fibres. The fraction of bast fibres in the stem is a direct measure for the potential recovery of bark pulp (de Meijer & van der Werf, 1994). Fibre length is important for its effect on the total length available for bounding (Horn, 1973). According to Wood (1981), a length of 3 mm is optimal. Hemp wood fibres are much shorter (on average 0.5 mm) which causes low paper strength. The evaluation included therefore, besides the assessment of the mass fraction of the woody core, also the estimation of the dimensions of its constituent fibres. The mass fraction of the woody core, correlates well with the recovery of wood pulp in the pulping process (de Meijer & van der Werf, 1994).

Accessions differed significantly for the mass fractions of woody core, bark and primary and secondary bast fibres (Figure 3). Levels of the estimated stem fractions were stable over years. Mass fractions of bast fibre from 15 up to 34%, were found in fibre cultivars of which those from Hungary had the highest contents. The smallest mass fractions of bast fibre were found in undomesticated populations, drug strains and also in fibre landraces. These accessions are represented by the concentration of data points between 9 and 15% bast fibre, content which can be considered 'natural' for *Cannabis*.

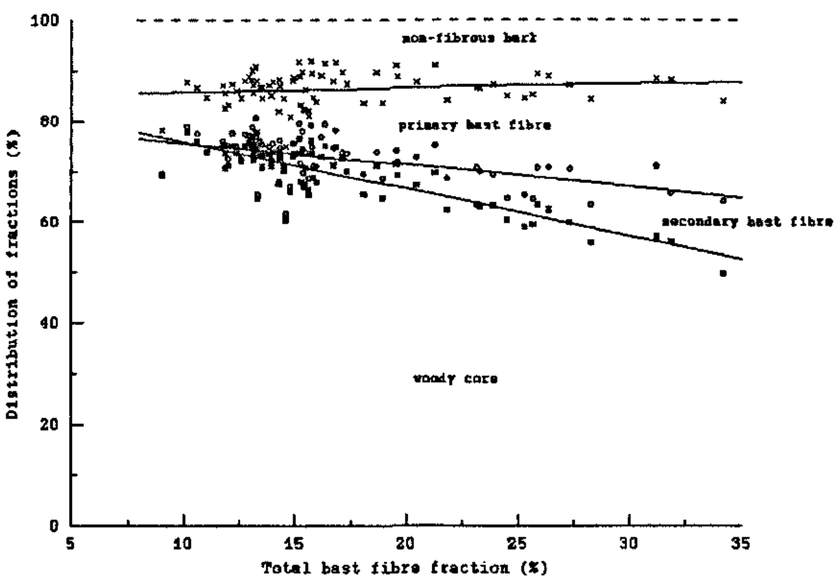

Figure 3: The distribution of various mass fractions in the stem in relation to the fraction of total bast fibre for 74 accessions.

The variation between accessions for wood fibre length and width was very limited. Mean fibre length varied from 433 to 613 μm and means for wood fibre width from 25 to 41 μm for very distinctive accessions (Figure 4). The stability of wood fibre dimensions over years was low. There was little interplant variation within accessions.

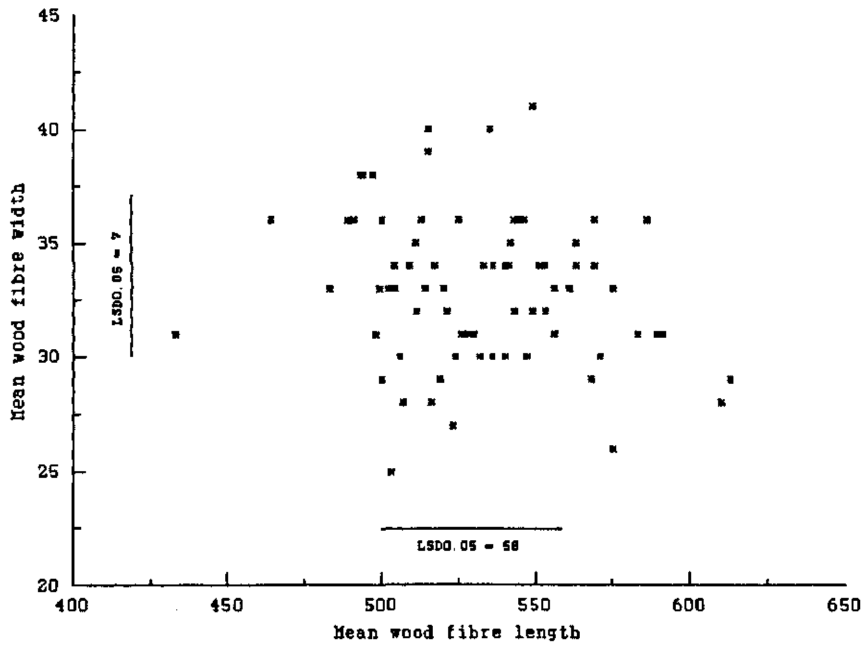

Figure 4: The mean wood fibre width (μm) versus the mean wood fibre length (μm) for 74 accessions tested in 1993.

Breeding for improved woody core quality is not very promising. The best way for genetic improvement of hemp pulping quality is a continued selection for increased bast fibre content, which implies a reduction of the woody core fraction.

RESISTANCE TO THE ROOT KNOT NEMATODE *MELOIDOGYNE HAPLA*

In the Netherlands, hemp is intended to be grown in an area with sandy soils and narrow crop rotations dominated by potatoes and sugar beet. Being a poor host for root knot nematodes (*Meloidogyne* spp.) is therefore an important precondition for the introduction of hemp. As hemp is generally considered to be a self-compatible crop, investigations should primarily focus on the effect of hemp on nematode populations with regard to other susceptible crops in the rotation. Recent research in the Netherlands indicated that some tested fibre hemp cultivars were, in relation to other crops, moderate hosts for *Meloidogyne hapla* and poor hosts for *M. chitwoodii*. The variation within the genus *Cannabis* in host reactions to *M. hapla* was tested by means of a seedling test and verified in a field trial (de Meijer, 1994). Seedlings of a large number of accessions were inoculated with a larval suspension and incubated for a period of one generation cycle of the nematode (6 to 8 weeks). The numbers of root galls and egg masses on the seedling roots were then counted and used to classify accessions according to resistance. Significant variation was found for these parameters which were considered estimates for nematode infection and larval multiplication, respectively. The lowest numbers were observed in the Hungarian fibre cultivar Kompolti sargászáru and in a wild Nepalese population. The highest densities were found in French and Russian fibre cultivars.

A subset of accessions was grown on a naturally infested arable field to study the relation between the seedling test results and host characteristics in the field. Hemp root samples, taken during the growing season, were examined to estimate infection in the field. After the vegetation period infestation in soil samples was estimated by extraction of second-stage juveniles of *Meloidogyne* and by bioassays with a susceptible lettuce cultivar. The ranking order of accessions for the number of galls in the seedling test agreed well with that for the number of galls in the field (Table 2).

Table 2. Accession mean number of galls per g *Cannabis* root fresh weight in a seedling test and in a field trial.

	Galls per g root fresh weight	
Accessions	Seedling test	Field trial (7 September)
Kompolti sargászáru	69 a *)	7.5 a
Kompolti Hibrid TC	113 b	13.8 a
883213	126 bc	10.1 a
Kompolti Hyper Elite	159 cd	24.5 ab
Fedrina 74	185 d	49.2 c
Futura 77	187 d	33.4 bc
$lsd_{0.05}$	42	17.7

*) Per column, means showing a common letter are not different at p=0.05.

The number of egg masses in the seedling test and the population density of *Meloidogyne* measured in soil samples from the field trial showed a comparable ranking of accessions but differences in the field were smaller and not significant. The population density of *M. hapla* in the field was not strongly affected by cultivation of *Cannabis*. The most resistant cultivar, i.e. Kompolti sargászáru, seemed to have decreased, and cv. Fedrina 74 seemed to have increased the population somewhat. So at present, Kompolti sargászáru, which combines a high level of resistance and a high agronomic value is already available. Selection within this cultivar, for increased resistance is possible. Selected, highly resistant individual plants, of this and other accessions can be used for cross breeding.

CANNABINOID CONTENTS

The presence of narcotic contents is an important reason for the decline of fibre hemp cultivation in the course of the 20th century. The concentration of cannabinoids in the inflorescence leafs is the most common measure to classify *Cannabis* according to psychoactive potency. Of the major cannabinoids, delta-9-tetrahydrocannabinol (THC) is generally accepted to cause the psychoactive properties of *Cannabis* preparations. Usually the concentration of THC is presented in connection with that of the other major cannabinoid, cannabidiol (CBD). A large part of the CPRO *Cannabis* collection has been classified according to the criteria in Table 3 (de Meijer et al., 1992).

Table 3. Criteria for the classification of phenotypes according to cannabinoid content.

Phenotype	[THC] (%)	[CBD] (%)	[THC]/[CBD]
Non-drug	<0.5	≥0.5	<1
Intermediate	≥0.5	≥0.5	
Drug	≥0.5	<0.5	>1

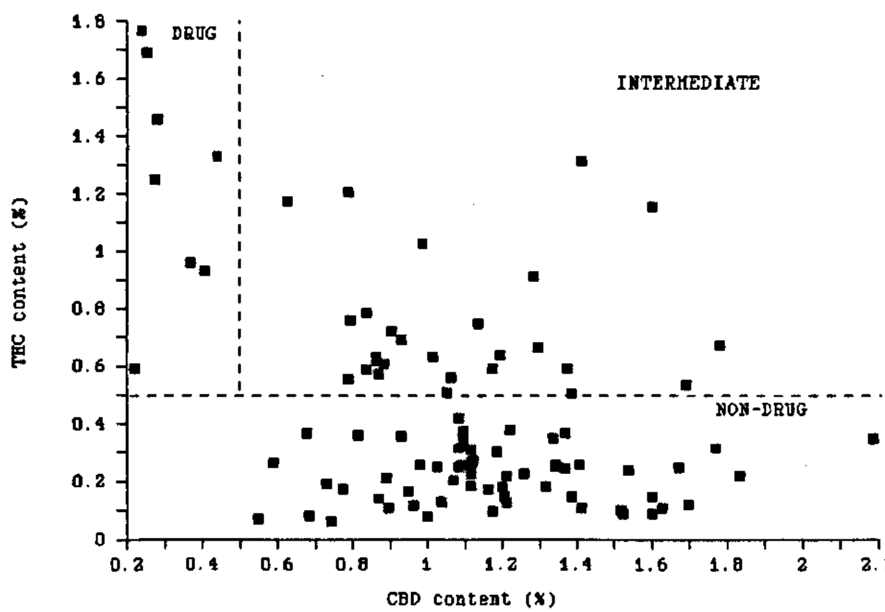

Figure 5: Mean THC content versus mean CBD content for 97 accessions tested in 1990. The areas of the phenotype groups are demarcated.

In Figure 5, a subset of accessions is assigned to the three phenotype groups. The non-drug group contains fibre strains and naturalized populations. The intermediate group comprises fibre strains and also accessions which are not used for fibre production, the latter often with considerable contents of THC but with too high CBD content to meet the criteria of the drug phenotype. The drug phenotype group contains marijuana strains but also selections from Hungary which are used as parents for hybrid fibre cultivars. Individual plants belonging to different phenotype groups can easily be found within one *Cannabis* population. Furthermore, accession mean chemical phenotypes are not very stable over years. In some cases accessions would be classified into different phenotype groups in different years. THC content is a more stable trait than CBD content.

Although usual, a high THC content did not necessarily imply a low bast fibre content. There were likewise no strict relations between cannabinoid contents and other traits. Breeding, either for high or low psychoactive potency, will not be hampered by strict linkages.

REFERENCES

Horn, R.A., 1973. Morphology of wood pulp fiber from softwoods and influence on paper strength. Presentation at the 58th Annual Meeting of the Technical Association of the Pulp and Paper Industry, Chicago. U.S. Government Printing Office.

Meijer, E.P.M. de, H.J. van der Kamp & F.A.van Eeuwijk, 1992. Characterisation of *Cannabis* accessions with regard to cannabinoid content in relation to other plant characters. Euphytica, 62: 187-200.

Meijer, E.P.M. de, & Soest, L.J.M. van, 1992. The CPRO *Cannabis* germplasm collection. Euphytica 62: 201-211.

Meijer, E.P.M. de, 1993. Evaluation and verification of resistance to *Meloidogyne hapla* Chitwood in a *Cannabis* germplasm collection. Euphytica, 71: 49-56.

Meijer, E.P.M. de & H.M.G. van der Werf, 1994. Evaluation of current methods to estimate pulp yield of hemp. Industrial Crops and Products, 2: 111-120.

Wood, I.M., 1981. The utilization of field crops and crop residues for paper pulp production. Field Crop Abstracts, 34: 557-568.