Hemp Husbandry

Robert A. Nelson

Internet Edition

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Hemp Husbandry

2.1 ~ Introduction

Edward Antil recommended the cultivation of cannabis in his *Observations on the Raising and Dressing of Hemp* (1777), thus:

"Hemp is one of the most profitable productions the earth furnishes in northern climates... It becomes worthy of the serious attention of the different legislatures of the northern colonies, of every trading man, and of every man, who truly loves his country.

"But as the people of America do not appear, from their present management, to be acquainted with the best and most profitable method of cultivating and managing this valuable plant, I beg leave to inform them of some things that may be of advantage to them." **(1)**

The anonymous Farmer from Annapolis also asserted the benefits of hemp husbandry in his *Essay on the Culture and Management of Hemp* (1775):

" Hemp is one of those plants which may be cultivated in many different situations, and in almost every different soil, no plant yielding, in our climate [New England], a crop more certain or more advantageous.

"A most peculiar advantage attending the culture of this plant, that it may be repeatedly sown on the same piece of ground, experience having shown that any dry land... properly prepared with manure, will produce much heavier crops than the richest fresh lands, and that the same piece of ground, assisted with a moderate quantity of manure, will admit of being successively sown, probably to the end of time, without any diminuation of crops.

"How easy therefore it is in every man's power to prepare, even on the meanest ground, a portion of ground sufficient to raise what is necessary to supply, at least, his family's wants? It will not require a fourth, perhaps not a tenth of the ground necessary to produce an equal quantity of flax...

"Hemp also produces a most certain crop, it being by no means subject to those accidents to which flax is exposed, from the uncertainty of seasons; rain, it is true, is necessary at the time of sowing, and it will indeed be something extraordinary if there doth not happen, during the course of ten weeks (for so long the season for sowing Hemp continues) a shower sufficient for this purpose, for its vegetation is so quick, that, in a very few days after it is sown, its leaves entirely cover and shade the ground, protect it from the scorching sun, enable it to retain the moisture, and prevent the seeds of the common weeds from sprouting. From this time the dews alone will prove sufficient to bring it to perfect maturity, and, indeed, heavier crops are produced on ground highly manured, in dry seasons, than in over wet years.

"The more we consider the nature and properties of hemp, and reflect how happily it is adapted to our climate and soil, the more reason there is to wish that the inhabitants of these colonies would avail themselves of its advantages...

"Nothing is wanted but the countenance, example, and encouragement of people of influence; and docility, attention, and industry in the poor...

"Now Hemp does not require half the rain that flax does; this is a circumstance that is well worth the notice and attention of every farmer; and therefore by his raising Hemp... he can with greater certainty supply all the necessary uses for his family; and by selling the overplus, he can purchase such things as his wife and daughters may think convenient on extraordinary occasions. This however need not hinder him from raising some flax every year. But I think that it is more for his interest to fix his chief dependence upon his crop of Hemp, as that is more sure, and in every way more profitable, the general run of seasons considered...

"From experience, then, we have reason to despair of raising flax in sufficient quantities to answer all our demands... A total neglect of flax is not intended to be recommended; where it succeeds tolerably, let the raising of it be continued, but the author hopes to be able to show, that, where the cultivation of flax cannot be carried on to advantage, Hemp may be substituted in its room, and will effectually answer, especially in coarse manufactures, every purpose to which flax hath been applied... Beneficent nature, which has made this plant so usefully, hath also most indulgently suited it to almost every climate, as well as to every sort of soil.**" (2)**

Timothy Painne, who edited M. Marcandier's *Treatise on Hemp*, was confident that his fellow Americans would be pleased to grow more of the crop once they learned of its many benefits. That seed of hope remains viable today:

"If they apply themselves to the cultivation of Hemp, and carry to perfection the methods of preparing it, what resources will they not find, in employment so profitable, and at the same time so easy? For to consider only its common qualities, it must be acknowledged, that it is a commodity absolutely necessary. The use of it extends to almost all the purposes of commerce and of life. There is no state nor condition that can be without it. The very person who cultivates it, is the first to make use of it for cloathing, and of all his labours, this is often the only fruit which he retains. There is a singular kind of circulation in this commodity; nothing that bears a near resemblance to it is to be found in the other productions of life. The more it is used, the more you increase its consumption. The cultivation alone is a labor that requires inhabitants, and the consumption of it serves to maintain them. In the different methods of preparing it, young men and women, old men and children, find employment, in proportion to their strength and ability. Some find business in preparing the ground and sowing it; others pull the Hemp, and water-brake it; others make ropes or cloth; all of them join in the consumption, and make use of it; and every one jointly and severally contributes to renew their work." **(3)**

John Bordley assures us likewise in his discourse on *Hemp* (1799):

"If the ground be good and well prepared, no crop is more certain than Hemp sowed in time and when the soil is moist. But, how uncertain is the tobacco crop! Failure of plants from frost, drought, or fly; want of seasonable weather for planting; web-worm, horn-worm, buttening low, for want of rain, curling or trenching, from too much rain; house-burning or funking whilst curing; frost before housed; heating in bulk or in the hogshead, inspection, culling, &c. Cultivating tobacco cleans, but exposes the soil to exhalation and washing away. It is only about a month that it shelters the ground: but Hemp shades it from May 'till about the first of August...

"A planter gaining 20 hogsheads of tobacco from 20 acres of ground, value 600 dollars, might expect 12,000 or 16,000 lbs of Hemp from the same ground, value 1,000 or 1,200 dollars. But, if the income from Hemp should be a fourth less than from the tobacco crop, yet I would, on several accounts, prefer the hemp culture." **(4)**

Edmund Quincey also offered his personal assurance to American farmers in a booklet on *Hemp* (1799):

"It may be expected, that, in the common way of [broadcast] sowing, an acre of good land will produce 7 or 8 bushels, but in the horse-hoeing or drill method, 10 or 12 bushels, and sometimes more. This makes the female Hemp more valuable than the male: and this must continue to be the case for some years in America, while this branch of husbandry is growing, as the American seed, may be more certainly depended on, than any from Europe: and indeed every husbandman who finds he has encouragement to encrease the quantity of his Hemp soils, will annually find a want of the greater part of his best seed, especially in a new country, abounding with so much suitable land for raising hemp, as these American colonies do; for which reason, the Farmer may for some years, almost assure himself, that what seed he can spare will produce him near the same price which he pays for the seed he purchases to begin with: this I mention as a

considerable inducement for him to begin upon this profitable branch of husbandry, and am persuaded, he will see the observation to be just..

"When he is told, that the same acre of land will yield him an equally good crop of Hemp, the third year, in case he plows it up as soon as the crop is pulled, and cross-plows it in about three weeks later; and will afford it a summer fallowing, and twice or thrice plowing the following year: I presume the Farmer will be inclined to make the experiment, altho' only upon a quarter of an acre, which I heartily recommend to him; and sincerely wish him success." **(5)**

Thomas Jefferson determined that, "A hand can tend 3 acres of hemp a year." About 20 man-hours per acre are required to produce a crop of hemp. The operations are: plowing, disking, harrowing, seeding, rolling, reaping, bundling, spreading, picking-up, breaking, hackling, baling, and transporting.

David Marcus compared hemp and three other crops in his study of *Commercial Hemp: An Economic Justification* (1997). He showed by comparison to canola, grain corn, and spring wheat, that hemp is by far the most profitable crop of choice:

"I estimate that growing for seed and fiber will generate long term combined revenues of $244-430/acre. The total expected costs of growing hemp for seed are $237/acre; even in a 'worst case' scenario, a minimum return of $7.25 is expected... This is slightly better than the expected return from spring wheat... The median expected hemp yields and prices generate expected returns which are more than double the next best crop, Ontario canola, and the highest estimates (which still should be considered conservative) are really quite exceptional compared to the other crops... Currently, hemp oil sells wholesale for approximately $38.50/kg. At an extraction rate of 25% and seed yields of 0.3-0.5 tons/acre, an acre of seed pressed for oil will gross C$2900-$4800." **(6)**

In comparison, spring wheat and canola cost $102.48 and $108.02/acre respectively. Production costs in Ontario (1995) were about $5/acre higher. Grain corn cost $202.79/acre, and canola cost $121.58. According to farmers' opinions expressed in the *Hemp Commerce& Farming Report* (May 2000; www.hemphasis.com), hemp grain must sell for about 35 cents/lb to be competitive with soy or flax.

Table 2.1 ~ Economic Profitability of Hemp for Seed & Stalk vs. Other Crops

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	Canola	Gr. Corn	Spr. Wheat	Low P/Y Hemp	Ave. H.	High P/Y H.
Av. Yield bu/ac	33	109	41	14.3 bu/ac +2.5 t/ac	19 bu/ac +2.75 t/ac	23.8 bu.ac. +3t/ac
Ave. $/Bu.	$ 6.30	$ 2.86	$ 3.59	$ 7.50/bu $ 55.00/t	$ 8.38/bu. $ 62.50/t	$ 9.25/bu $ 70.00/t
Total $$	$207.00	$311.74	$147.19	$244.75	$337.45	$430.15
Total Costs	$166.55	$277.80	$140.39	$237.50	$237.50	$237.50
Return ($/ac)	$ 41.35	$ 33.94	$ 6.80	$ 7.25	$ 99.95	$ 192.65

Table 2.2 ~ Approximate Production Costs ($/Acre) in Saskatchewan (1996)
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Expenses	Hemp Fiber	Hurds	Seed
Cash Operating Costs	$ 22.9 kg/ac	$ 29.2 kg/ac	6.0 kg/ac
Seed	$ 45.11	$ 57.49	$ 11.83
Fertilizer	$ 29.20	$ 29.20	$ 29.20
Chemicals			
Herbicides	0	0	$ 7.30
Insecticides	0	0	$ 3.65
Machinery Operation			
Fuel	$ 6.94	$ 6.94	$ 6.94
Repair/Maint.	$ 18.98	$ 18.98	$ 18.98
Hired Labor	$ 5.84	$ 5.84	$ 5.84
Crop Insurance Premium	$ 5.11	$ 5.11	$ 5.11
Utilities	$ 1.20	$ 1.20	$ 1.20
Miscell. Overhead	$ 1.83	$ 1.83	$ 1.20
Building Repair	$ 0.84	$ 0.84	$ 0.84
Property Taxes	$ 2.74	$ 2.74	$ 2.74
Interest on Operating	$ 2.80	$ 2.80	$ 2.80
Total Cash Costs (A)	**$125.42**	**$137.82**	**$103.11**
Machinery Depreciation	$ 20.99	$ 20.99	$ 20.99
Building Depreciation	$ 0.84	$ 0.84	$ 0.84
Machinery Investment	$ 12.78	$ 12.78	$ 12.78
Building Investment	$ 1.35	$ 1.35	$ 1.35
Land Cost	$ 16.79	$ 16.79	$ 16.79
Labor & Management	$ 13.87	$ 13.87	$ 13.87
Total Non-Cash Costs (B)	**$ 66.61**	**$ 66.61**	**$ 66.61**
Total Cost (A+B)=(C)	**$192.06**	**$204.44**	**$169.73**

2.2 ~ Soil

It is imperative to analyze soil samples before commencing to sow hemp. Tests should be performed to determine pH, levels of organic matter, and macro- and micro-elements. Soil pH should range between 6.3 to 7.8, and it should contain at least 3.5% organic matter (more is better). Phosphorus should be at least >40 ppm, potassium >250 ppm, sulfur >5000 ppm, and calcium <6000 ppm. The ratios of elements also should be determined. For example, high levels of calcium bind phosphorus and make it unavailable to the plants --- a problem that can be avoided by testing the soil.

Hemp should not be sown on spring-plowed sod. The plowing depth should be about 8 inches so as to give a deep bed for root development. Less than 6 inches of plow-depth gives much lower yields. The land should be given a deep plowing in the fall so the winter weather can crumble the soil. After the field is furrowed, the topsoil is packed and smoothed with a ring roller. It must also be smoothed finely with a disk harrow in the spring. If the topsoil cracks open after sowing, the cracks must be cleared away with a hoe or roller.

The timing of fall plowing significantly affects the overall yield of the following hemp crop: the sooner, the better. Late plowing reduces yields by as much as 30%.

The USDA *Farmer's Bulletin* No. 1935, entitled "Hemp", was issued to farmers in 1943 to initiate them to the subtleties of hemp cultivation. The bulletin advises:

"Hemp should not be grown on poor soils. To obtain good yields and fiber of high quality, it is necessary to have a growth of uniform stalks 6 to 8 feet long. Short stalks, from poor nonfertile lands, seldom produce a high-quality fiber... [Hemp grows well in the Corn Belt, but] if land will not produce from 50 to 70 bushels of corn per acre, it should not be planted to hemp for fiber production." **(7)**

A report by Lyster Dewey in the USDA *Yearbook* (1913) states:

"On the best farms the crop is cultivated four times --- twice rather deep and twice with cultivators with fine teeth, merely stirring the surface." **(8)**

During World War II, the German government published *The Humorous HempPrimer* to educate farmers and encourage its cultivation. Moor land was recommended as proper ground for hemp. That is true, *but only for seed hemp*, not fiber crops:

"He who grows hemp in the moor is carrying on true moor-culture since the options are quite limited: the moor farmer grows potatoes, cabbage, and some grains as well as corn. Little else can grow here.

"When growing other crops in the marsh, even if the seeds sprout nicely, the weed growth is extensive. Hacking and hoeing without rest, as the moisture seeps out, the moor gets dusty and useless. The farmer's efforts are constantly hindered by strong weed growth.

"Here the mighty hemp plant enters as saviour of the moor lands. It grows quick and large and helps cultivate the lands. Most any crop is happy to alternate with hemp, since hemp's shady umbrella forces weeds to their knees. It keeps the moor ground dark, clean and healthy. Also the moor's tendency to late rust doesn't bother hemp a bit. Even virgin soil in the marsh can yield weak hemp production. However, when properly drained, hemp performance is quickly improved. In short, marsh values are increased by sowing hemp!

'In many areas, both in mountains or valleys, hemp removes many inherent weaknesses of the soil if first one lowers the groundwater level... [to] at least 50 cm [20 in.] below the surface." **(9)**

The USDA advised to the contrary in *Farmers' Bulletin* No. 1935:

"Muck or peat soils are not recommended for the production of high-quality hemp fiber. The quantity of fiber produced per acre on these soils may be very high, but experience has demonstrated that the fiber lacks strength, which is the first requirement of hemp fiber for good cordage."

In his *Treatise of Hemp Husbandry* (1775), Edmund Quincey recommended an additional plowing after mellowing the soil:

"The last time the ground must be plowed in ridges of about six feet wide, flat and even on the top as they can be laid, with a small interval between each ridge, sufficient for the pullers to pass, when the male hemp is ready for pulling.

"The reason why the ridges are to be made thus narrow, is for the more convenient pulling of the male Hemp, which is always pulled several weeks before the female... being sowed in ridges you are enabled to pull the former, without bruising or otherwise damaging the latter, which is very prejudicial to the crop."

Hemp loosens, mellows, and shades the soil, and the fallen foliage forms a mulch that preserves moisture and bacteria in the soil. The root system decays quickly after the harvest. Up to two-thirds of the organic matter returns to the soil if hemp is field-retted. Hemp depletes some humus; nonetheless, it is easier on the land than any other crops except alfalfa and clover.

2.3 ~Water

Hemp requires at least 20-30 inches of rainfall during the growing period, and irrigation is necessary if precipitation is less than adequate. Abundant moisture is needed during the germination period. The absorption of water by hemp increases daily until flowering begins. Then the uptake of water decreases considerably, with a subsequent increase occurring at late flowering and during seed formation. In total, 80-130 gallons of water are required to produce 1 kg of dry fiber. Hemp uses twice as much water in light soil than it does in medium soils. There is also a significant correlation between soil moisture and cannabinoid content.

L. Slonov performed extensive tests from 1975-1977 to determine the correlation between water supply and ATPase enzyme activity in hemp:

"The optimal water deficit for normal metabolism in hemp plants was 7-15% of total leaf saturation. Soil moisture should not go below 80% of total moisture capacity during hemp ontogenesis." **(10)**

USDA *Farmers' Bulletin* No. 1935 had this to say about water:

"Drought conditions, if accompanied by high temperatures, appear to hasten maturity before the plants are fully grown... Hemp requires a plentiful supply of moisture throughout its growing season, especially during the first 6 weeks. After it has become well rooted and the stalks are 20 to 30 inches high it will endure drier conditions, but a severe drought hastens its maturity and tends to dwarf its growth. It will endure heavy rains, or even a flood of short duration, on light, well-drained soils, but on heavy, impervious soils excessive rain, especially when the plants are young, will ruin the crop.

"The hemp plants in puddled areas of a saturated field will be ruined within two days; it is imperative that the field be well-drained. On the other hand, if the slope of a field is too steep, precipitation will run off the field before it can be retained. If excess winter moisture or heavy rains are likely, the field should be plowed with water-furrows every 30-40 feet, leading to drainage ditches."

Irrigation --- Three-fourths of the farmland in America could grow hemp up to 15 feet tall if adequate water was available; irrigation is therefore recommended. G. Kr'stev and I. Furdzhev conducted a study of the effect of irrigation on hemp; the yield of dry stems increased by 20%.

The practice of cultivating hemp under irrigation was developed by George W. Schlichten (inventor of the decorticator of that name). He published a small treatise on the subject, providing the following instructions:

"The land upon which hemp is to be grown by irrigation must, of course, be level within the checks, so as to assure an even and thorough irrigation... [After plowing and harrowing,] the checks are to be made and they may need some leveling within the checks. The size of the checks will vary according to the lay of the land and the volume of water available for irrigation. The checks can be made in the same manner and of the same size as those for alfalfa."

"Before planting the hemp the land must be thoroughly irrigated, which is best done by making a number of cross checks within the borders. Within these cross checks the water should be held until the ground is thoroughly soaked. This insures a perfect seed bed and an even germination of the seed.

"As soon as the land is dry enough for working it should be thoroughly loosened up by a spring tooth harrow going lengthwise within the checks...

"Referring to a general practice, the first irrigation of the growing hemp should be given when it is needed, or when it will do the most good, as the timely first irrigation is, so to say, the making of the crop, as far as the stand is concerned. The time to give the first irrigation is when the young hemp plants do not continue a vigorous growth, or indicate otherwise the lack of moisture in the ground, whether they are 6 inches above the ground or 2 feet.

"For the experienced grower it is best that the first irrigation is given as soon as the plants are tall enough to shade the ground. If irrigated before that time, because of lack of moisture in the land, the surface of the ground is liable to cake or harden, and that would necessitate another irrigation about a week or 10 days thereafter, which will bring about that the plants shade the ground.

"The land should be level within the checks and with good solid borders, so there will be no trouble to irrigate properly and thoroughly, covering every part of the check sufficiently with water. If borders have to be reinforced or cross-checks have to be put up by shovel when irrigating, then a certain percentage of the crop is destroyed, to say nothing of the time and labor that have to be applied. It therefore pays to prepare the land right before planting.

"No water should be left standing in the checks, and the ends of the checks must be drained a few hours after the irrigation, or the end water can be let into the adjoining check that is to be irrigated next.

"The subsequent irrigations usually follow at an interval of about 2 or 4 weeks, according to the condition of the soil or weather. The crop must be kept growing steadily and according to that the irrigations have to be timed. Failure to irrigate when it is necessary is liable to stunt the crop, and that checks the growing."

2.4 ~ Temperature

Tamm determined that hempseed needs a minimum temperature of 1-2° C for germination and emergence. It should not be sown until the soil temperature rises to 10° C. The optimum temperature is 35° C; the maximum is 45° C, at which temperature the seeds sprout within 12 days.Young hemp plants can survive frost as low as -5° C, but the plants will stop growing even if warm weather follows. The temperature range for hemp growth is 19-25° C (66-77° F). Hemp enters into its rapid growth stage (about 2 inches/day) when the average temperature rises to 16° C (61° F). If southern varieties of hemp are grown in northern latitudes, however, the fiber might not attain technical maturity within 110-115 days, and certainly their seeds will not ripen. The farmer must consider this when selecting a hemp cultivar for his location.

C. Richez-Dumanois, *et al*., studied the *in vitro* propagation of hemp clones, thus:

"Morphological and chemical development decreased at low temperature and was promoted by a regime of 22° C (daily temperature) and 17° C (night) under 24 hour illumination and 70% relative humidity." **(62)**

The phenotypic expression of cannabis is strongly influenced by the temperatures of the soil and air. This effect can be used to advantage in breeding. C. Nelson conducted such experiments with these results:

Air 30° C/Soil 30° C: Maximum elongation, number of nodes, leaf abscission, and water consumption; earliest maturation; minimum leaf area; many staminate flowers.

Air 30° C/Soil 15° C: Maximum stem weight; minimum plant weight; many staminate flowers.

Air 15° C/Soil 30° C: Maximum leaf size, stem diameter and weight; sex reversals from pistillate to staminate.

Air 15° C/Soil 15° C: Maximum leaf area and root water content; minimum water consumption; latest blooming; many pistillate flowers with sex reversals from pistillate to staminate.

During the flowering phase, the optimal temperature is 16° C (61° F) during the critical night period, and 28° C (80° F)during the photoperiod.

2.5 ~ Sowing

Hemp may require up to three years to acclimatize to a new locale. This fact has caused problems for many new hemp farmers, who expected much higher yields than they actually achieved. It is recommended that experimental plots of seed hemp be grown to develop a localized strain before committing to large-scale cultivation. The best variety must be selected with careful consideration for the differences in yields of seed and stalk, maturation (early or late), and fiber content, etc; an error in this wise can result in a shortfall of 30% or more.

The art and science of producing the finest quality hemp fiber requires that perfect seed be sown at the proper time in prepared soil. Good hempseed is bright gray and plump, and has a nutty taste. White seed will not germinate; green seed is unripe, germinates slowly, and produces weak plants that are smothered by more vigorously growing hemp. Black seeds have fermented due to improper drying after harvesting; they taste rancid.

The USDA warned farmers about "lint seed" (linseed):

"In some instances seed is saved from hemp grown for fiber but permitted to get overripe before cutting. This is known as lint seed. It is generally regarded as inferior to seed from cultivated plants. A good crop is sometimes obtained from lint seed, but it is often lacking in vigor [heterosis] as well as germinative vitality, and it is rare that good crops are obtained from lint seed of the second or third generation."

One bushel of hempseed weighs 21 kg (44 lb). If hempseed is good, at least 95% will germinate, though a germination potential of 85-90% is considered to be acceptable. The water content should be about 12%. **(11)**

As of 1998, only 44 registered varieties of hemp exist, and only 32 are available. Such an extremely limited base could make hemp crops vulnerable to devastating blights. The gene pool is acclimatized to 45-55^{o} N latitude (Europe, Canada, and the northern states of the USA). The IHA has recommended that tropical germplasm, which contain high levels of psychoactive THC, be drawn upon for development.

The most popular French varieties are the monoecious Ferimon-12 and Futura-77, hybrid Fedora-34, and Fedrina-74. The Hungarian variety Kompolti, bred by the renowned hemp breeder Dr. Ivan Bocsa, contains 35-38% "technical" fibers, with a maximum yield of 12 tons/hectare within 115 days. Other available Hungarian varieties are Uniko-B, Fibriko, and other Kompolti cultivars. They are marketed by Fibro-Seed Gmbh (H-3356 Kompolt, Hungary). The hemp grown in Asian countries are landraces, not cultivars, and have little economic significance in Europe. In America, however, Kentucky hemp was developed from a cross of Chinese and European cannabis. This gene pool has become feral since 1937 and needs to be redeveloped. Canadian farmers are permitted to grow about two dozen varieties of seed, including Anka, the first Canadian cultivar.

The yield and quality of fiber is strongly influenced by the seeding rate. Hempseed is sown at the rate of at least one bushel per acre, and up to 5 pecks is common. Germination will be uneven if the seed is planted deeper than 1.6 inches. Shallow seeding also produces erratic germination. The seeds must not be covered more than one-half inch deep. Roller disk drills give better results than tooth drills, and rolling the land after seeding benefits the crop. When compared to other methods, strip sowing considerably improves all the qualitative indices of hemp fibers. **(12)**

S. Losev studied the effects of seeding rates and methods of sowing hempseed. He concluded:

"With continuous sowing of hemp in rows spaced at 15 cm, on well-fertilized soil, about 100 kg/ha of 100% valid seed should be sown (4.5 million seeds). With close-spaced drill sowing (with the rows spaced at 7.5 cm) the rate must be raised to 120 kg/ha (5.5 million seeds). With a shortage of seeds, and on weedy soils, sowing should be carried out in

close ribbons (22.5 x 7.5 cm) with a seeding rate of 60-80 kg/ha. This method allows for a single inter-row hoeing." **(13)**

The Czeckoslovakian hemp breeder F. Baxa reported these results of his experiments with sowing density:

"On fertile soils greater yields were obtained when sown in rows 7.5 and 12.5 cm apart. Soils with lower fertility yielded significantly more stalks and fiber when sown in rows 22.5 cm apart. In both cases a seeding rate of 100 kg/ha proved best." **(14)**

Extensive tests have shown that the best growth of a small crop of seed hemp is achieved when the seeds are planted in mounds at least one yard apart, at a rate of a dozen per mound (10-15 kg/ha). When the plants are about a foot tall, they must be thinned to only 4 or 5 per hill, or one plant per 20 inches. Good stands cannot be obtained with thin seeding, and good plants cannot be obtained without thinning. Large crops of dual-use (fiber and seed) hemp are planted in rows up to 16 inches (40 cm) apart. It is sown at a rate of 12-20 kg/ha (60-100 plants/m^2), depending on the row spacing, with 7 seeds per linear foot of row (20 grams per thousand grain weight). When grown for seed alone, hemp is sown in rows at least two feet apart with only two or three seeds per foot. Seed hemp should not be grown more than 800 feet above sea level, because the seeds probably will not mature in due time, even if it is an early variety. **(15)**

The Anonymous Farmer recommended this plan for cultivating a crop for its seed:

"A far better method is to raise the seede apart by itselfe, either on a portion of the ground allotted for the HEMP, or what would be yet more proper, on any good spot that is convenient for this purpose, which must be reduced into proper tilth... This ought to be done as soon as the frosts are over, for, provided that the weather is mild and will permit, the earlier what you intend to raise seed from is put into the ground the better, not only because the forward plants bring their seeds better to maturity, there will be time to sow the ground again.

"The season for sowing being come, the ground should be laid off, either with the plow or hoe, into flat hills, about 4 feet asunder, in each of these hills, about 10 to 15 grains of the HEMP seed may be deposited, and as soon as they are sprung to such a height as to be past danger from frost, or other accidents, the hills ought to be thinned, pulling up the superfluous stalks, leaving about 8 or 9 plants in each hill... An acre of ground, managed in this manner, will produce from 20 to 25 or 30 bushels of seed."

Thomas Jefferson noted the following in his farm journals:

"To make hemp seed, make hills of the form & size of cucumber hills, from 4 to 6 ft apart, in proportion to the strength of the ground. Prick about a dozen seeds into each hill, in different parts of it. When they come up thin them in two. As soon as the male plants have shed their farina, cut them up that the whole nourishment may go to the female plants. Every plant thus tended will yield a quart of seed. A bushel of good brown seed is enough for an acre."

Edward Antil offered these considerations in his *Observations*:

"If you have no convenient place to sow your seed Hemp by itself, then sow a border of 6 feet wide along the north and west sides of your Hemp field; the reason of sowing your seed Hemp in such narrow ridges or borders is that, when the carle or he Hemp is ripe, and has shed its farina on the fimble or female Hemp, by which the seed is impregnated, and the leaves of the carle hemp fall off and the stem grows yellow, you may easily step in along the sides and pull up the carle Hemp without hurting the female, which now begins to branch out, and looks of a deep green colour and very flourishing, and when the seeds begin to ripen, which is known by their falling out of their sockets, you may all along both sides bend down the plants and shake out the seed upon a cloth laid on the ground, for as they ripen they scatter upon being shaken by a hard wind, or otherwise, then it must be watched, and the fowls... kept from it, for they are immoderately fond of the seed."

Fiber hemp crops are thickly seeded using a standard grain drill or modified alfalfa seeder, at a rate of 55-70 kg/hectare (ha = 2.47 acres). The row width should be 4 to 8 inches, and not more than 10 inches. Field studies have shown that the maximum yield of dry plant matter is obtained with a seeding rate of no more than 80 kg/ha (70 lb/acre). Excessive seeding will produce hemp of insufficient height and no value to the farmer. The optimal plant density is about 160 per square meter in nitrogenous soil, up to 260/m^2 in mineral soil. The percentage of bast fiber increases with the seeding rate. 40-50 kg/ha will yield about 200 plants/m^2 at emergence, self-thinning to about 140/m^2 at harvest. Tests conducted in 1972 by J. Ritz determined that there was no influence of stand density on the yield of stems with 100, 125 and 150 plants/m^2.

Analyses of modern fiber hemp production in The Netherlands indicate that crop productivity can be improved by earlier sowing, albeit at risk of suffering from frosts. According to an idealized crop growth model, sowing on April 15 and harvesting on September 15 should yield about 1 ton/ha of dry stems. Sowing on April 1 would increase the yield by 2.3 tons/ha. Sowing on April 30 would reduce the yield of stems by 1.4 tons/ha; sowing on May 15 would reduce the expected yield by 3 tons/ha.

At latitudes south of 35^o hemp can be planted in any month if there is sufficient moisture to germinate the seed before solar heat kills it. That can be prevented somewhat if the seed is covered two inches deep and lightly harrowed.

In the USA, at the latitude of New York City/Indianapolis, hemp can be sown as early as March 25, and harvested in the last week of June. A second crop can be sown and harvested early in October. Only one crop can be planted north of 40^o latitude.

If the field has been prepared for irrigation as described by George Schlichten, the following method should be applied:

"The seeding should be done crosswise over the checks, across the borders and about 10 checks can be seeded at a time. By seeding across the borders, all the land is made productive and the stand will be uniform in size of stalks. If the borders are not seeded, the hemp that grows alongside of same will produce big and branchy stalks (flange stalks) which make an inferior fiber and therefore reduce the average quality of the hemp.

"After seeding, the loose and porous land should be lightly rolled across the checks the same way as the seeding was done; the heavier and more compact soil should not be rolled, but harrowed within the checks, that is, parallel to the border, as harrowing across the borders would reduce their height too much, but the teeth of the harrow must be set slanting."

USDA *Farmers' Bulletin* # 1935 offers another suggestion:

"A good practice in planting hemp for fiber production is to sow around the edge of the field next to the fence a 16- to 18-foot width of small grains, which may be harvested before the hemp. Space is thus provided for the harvester to enter the field and begin cutting without injuring the hemp. It also prevents hemp plants at the edge from growing too rank. Uniform plants are necessary for uniform fiber quality."

Wind and changes of temperature will harden the lignin and render the fibers coarse and "harsky" (harsh). It is important that the stalks grow close together under the shelter of their foliage, thus creating a favorable micro-climate among the plants.

Edmund Quincey recommended this method of sowing hemp, "as has been very exactly experienced":

"The Farmer being sure of good seed, and given his ground the last dressing, and thereby laid it as fine and level, as the border of a garden; the seed must be sown as carefully and regularly as possible, and as it is very tender, and will bear but a slight covering, care must be taken, lest by burying too deep, the vegitation may be prevented. Clods left unbroken with the Harrow and Roller, have the like effect upon much of seed, in the common method of sowing: Negligence in this respect has often ruined more than one-third of a Crop; for a great part of the plants will rise irregularly, and getting bad habit in their first shooting, the produce will be small.

"The preparation of the soil in the drill way of sowing hemp-seed, is the same, as in the common way. The seed must be planted in double rows, with ten or twelve inches partition, and with intervals, for the passage of the hoe-plow, from three or four feet broad, as the soil may be more or less rich; the richer the soil, the narrower may be the intervals. The seed must be planted and covered very shallow, and is not safe in general if covered deeper than about half an inch, unless in very light soils, in which it may grow at one inch depth.

"The seed let into the ground by the drill is less in danger from birds, because it is all covered; but yet may be watched to prevent their getting at it very early in the morning, and towards evening...

"When the Hemp is four or five inches high, the Farmer sends into the field careful laborers with hand hoes, to cut up weeds which may rise in the partitions; once is sufficient, as thereby by the Hemp gathering much strength, it will prevent their rising any more. When the partitions are cleared by the hand hoe, then let the horse-hoe plow be set to work in the intervals, and with this let all the ground between the double rows be turned up deep and broke fine. The weeds will be destroyed by this, and the whole soil made fit to receive the roots, and nourished for their support. The good effect of this kind of husbandry, is in no other respect seen more evidently. The fibres of the roots of Hemp

even in the most favorable soils, do not naturally spread, but lie in clusters about the base of the stock, their numbers answering for their shortness, but in the horse-hoeing way, the fibres of the plants of the two opposite rows will meet across, and fill the intervals, and the plant will flourish accordingly... by this means the ground will be several times enriched, while the crop is growing... [the soil] will retain so much of the nitrous quality of the dews and rains, as will render it abundantly capable of producing several crops, though the soil be but of a midling goodness... herein the Farmer is supposed to change his partitions each succeeding year, into the intervals of the past year's crop, these being enriched by the hoe-plow cultivation..."

Lionel Slator gave this advice in his *Instructions* to farmers:

"In the sowing of Hemp, great Care and Judgment ought to be used, that it be not sowed too thick or too thin: In the first Case, it would be apt to lodge, and so lose the crop; In the second, the Hemp will run more to Bunn [coarse] or Straw, than it will to harl or Skin."

Edward Quincey also noted this:

"It is observed by some Farmers, that sowing early thickens the harle or coat of the Hemp."

John Bordley gave notice to this in writing of his experience with *Hemp* (1799):

"My hemp never suffered materially from drought but once, and that of a sowing in May. It was never found necessary to weed what was sowed for a crop: but only such as was sown very thin for producing seed. Sometimes seed was saved from the margin of the field, where the plants had room to branch and were coarse..."

Edward Antil assured early American farmers that they could prophesy truly if hempseed was sown wisely, according to his *Observations on the Raising and Dressing of Hemp*:

"The ground being moist as I said before, but by no means wet so as to clod, which would ruin the crop, and nothing after that, but too much wet, will hurt it... Whereas if the seed be sown, when the ground is dry, the seed that lies deepest where the moisture is, will come up first, and these will shade and starve those that come after, by which means the first comers will be too large, and the last will be much too small, so that the crop will be damaged in every way: So much depends on this one circumstance of sowing the seed when the ground is moist and fit to receive it."

The anonymous 18th century "Farmer from Annapolis" emphasized the importance of right timing in sowing hempseed:

"It may be necessary to observe, that as the Hemp which is first sown, provided it does not meet with any accident, most commonly, yields the heaviest crop... It is however by no means eligible to sow this seed, till you can reasonably expect that no danger is to be apprehended from the frost; nor is it by any means proper to sow when the ground is very dry, or that there is an appearance of a continuation of dry weather; in either of these cases, it will be far more prudent to delay the sowing for a little... the first opportunity ought to be taken to sow the seed, either immediately before a rain, or as soon after as the

ground will admit; sowing before the shower ought to be preferred, only because the seed will be covered much better and more equally when the ground is dry, than when it is wet: immediately before sowing, the ground must be laid level with the harrow, and the best and quickest method of covering the seed is, either with a short toothed single harrow, or a bunch of brush, which ought to be dragged once or twice over the land, and directly after, a wooden roller of 15 to 18 inches diameter ought to be run over it; when there is only a small piece of ground sown, the seed may as well be covered with a garden rake..

"As all kinds of birds, but more particularly pigeons and turtle doves, are remarkably fond of this seed, and will, if they are permitted to frequent the ground, destroy great quantities of it, even during some days after it is sprung up; it is necessary to keep them off until it has gathered strength, and the leaves become expanded... No further attention is requisite, until the season for pulling, unless it is to observe that your inclosure is sufficient to keep out such animals as might trample or break it."

Hemp was given extensive treatment in the *Fan Sheng-chih shu*, a Chinese treatise on farming written circa 25 BC. Farmers were advised to avoid the *ch'en* (the 5th in 12) day of the sowing period. Twenty days before being sown, the seeds were treated by immersing them in a decoction of powdered horse bones, aconite, silkworms and sheep dung. They were immediately dried in the sun, then stored carefully, and immersed again just before planting. If horse bones were not available, melted snow could be used instead:

"Snow is the essence of cereals; it causes crops to be drought-resistant. Always take advantage of winter to store snow; fill containers and bury them in the ground... If seeds are treated like this, the harvest will regularly be doubled...

"If you plant hemp too early [the males] will be hard and rigid, with thick skins and many knots. If you plant late then the skin will not be hard. It is better to err in being early than to err in being late."

Ji Sheng's Book (Western Han Dynasty, 206 BC-24 AD), instructed farmers thus:

"If the sowing time is early, the fiber will be thick and strong and can be harvested early. Otherwise, the fiber will not be mature. It is better to sow hemp seed early instead of late...

" First, soak the seed in water and sow them as soon as they germinate. Soak the seed in water for about the same time required to cook... rice. Then spread the soaked seeds on the bamboo bed for about 3 to 6 *cun* [inches] in thickness. Stir the seed several times and after one night they will germinate... Second, in order to avoid plant diseases and insect pests, hemp should rotate with wheat, beans, and cereals. Third, different methods should be used with different soil moistures.

"Disperse the sparrows for several days in order to protect the seeds... When the seedlings have grown for some time, thin out the weak ones so that... good seedlings can grow well."

The venerable *Qi Min Yao Shu* ("Essential Arts for the People", written circa 500 AD) gave these instructions to farmers:

"Generally, male hemp seeds are white. There are two ways to examine the quality of the white seeds. The first is to bite a seed with the teeth, and if the inside of the seed is very dry, it should not be sown. Otherwise the seeds can be sown. The second method is to put the white seed in the mouth for some time. The seeds that do not turn black are good."

Farmers in India sometimes soak the seeds overnight in milk and water before sowing. A traditional Chinese method of stimulating the germination of hempseed is to soak them in an aqueous extract of the plant. According to V.E. Sustrina, this also increases the number of females:

"Hemp seeds were soaked at 10-15^{o} C in extracts of dry inflorescences; the percentage of staminate plants was greatly reduced." **(19)**

In 1924, Luigi Leggieri described his experiments with pre-sowing treatments of hempseed:

"*Confettatura*: a dry method [causes] an organic fertilizer (poudrette, meat powder, bone dust, pulverized sheep manure, pigeon or chicken dung, etc.) to adhere to the seed. The adhesion is facilitated by adding the fertilizing materials to clay and then rolling the seed in this or by the use of gum arabic. Nutritive baths (immersing the seed in water or in solutions of K-sulfate, ammonium nitrate, Na-nitrate, dung, etc.) and disinfectant baths (using solutions of Cu-sulfate, arsenic lime and special preparations) belong to the wet method. Plot tests with hempseed, previously immersed in water, 1% and 3% potassium sulfate solutions and 1% and 3% ammonium nitrate solutions for 6, 12 and 24 hour periods, lead to the general conclusions that (1) the immersion in water has a favorable reaction, (2) the action of saline solutions varies with the seed; sulfate solutions act favorably on the hemp seed, (3) the duration of immersion has a great influence and hence it is necessary to find the optimum duration for each species. **(17)"**

Research conducted by J. Stephan in 1928 showed that ortho-phosphoric acid will stimulate germination when used in 1% concentration for 1/2 to 1 hour even in daylight, which usually inhibits the germination of hempseed.

G. Weeber reported his similar experiments, thus:

"When distilled water was used, germination occurred at least twice as quickly. A further acceleration was obtained by using a 30% solution of hydrogen peroxide; hemp seeds germinated within 12-24 hours." **(18)**

Hempseed can be induced to sprout within 12 hours if it is soaked in a solution of Mg-sulfate (0.8 % Epsom salt) or MgCl and then steamed with ether. Treatment with a 1% solution result in damage to the seeds. Germination occurs within 10 hours when hempseed is soaked in Mn-sulfate (1.5%) plus ether treatment, or with Pb-nitrate (0.5%) without ether treatment. Sprouting takes place within 6 hours when seeds are soaked in a solution of oxalic acid (1%), with or without ether treatment. The germination percentage is higher in darkness than in light. The resulting plants produced up to 88% increase in the dry weight of stems, and the plants' height increased up to 26%. The dry weight and

height of the stems varied with formulas of the solutions; therefore this method can be used to improve plants in a systematic manner. Dry ether alone has no such influence; it is effective only in combination with the chemical solutions.

Treatment with carbon dioxide or ethylene before sowing influences positively the growth, budding, flowering, and ripening of hemp. Root development, seed production and total yields also are greatly increased by such treatment.

2.6 ~ Cultivation

Hemp intercrops happily with corn, mustard, broccoli, brussel sprouts, lupine, nettles, hops, and turnips. Hemp is not compatible with tobacco, spinach, cress, pepperweed, or vetch.

The Humorous Hemp Primer offered this encouragement:

" Hemp is not demanding of prior crops. It grows well after fruits, vegetables, grasses and grains. Moreover, shady hemp... does provide the best prior crop, because its tall, wide, dense growth strangles weeds. After hemp, all grains grow well and without problems. Also, fruits which follow hemp bring larger crops, as do grasses, delicate and tender when they lie down in hemp's bed. In short, anything sown in hemp's fields will bring rich harvest and much money."

The USDA *Farmers' Bulletin* No. 1935 noted:

"Old pastures plowed up [in the fall] are well suited for hemp culture. Fields previously cropped to soybeans, alfalfa, and clover are excellent for hemp. A good rotation is to follow corn with hemp, and in Kentucky a fall cereal may follow the hemp.

"When planted after fiber hemp, the yield of winter wheat is often increased as much as 10-20%. This cannot be done after a crop of seed hemp, because it is harvested late in the season."

The introduction of hemp as a new crop into the cycle of crop rotations can help reduce the incidence of diseases and soil pathogens. Hemp improves soil structure, suppresses weeds, and is nearly free of diseases and pests. In ordinary schemes of crop rotation, hemp can occupy the same place as oats or beans. Hemp also responds well to a preceding crop of wheat, peas, or potatoes, but should not follow sod, timothy, or small grain. In latitudes below 40^{o}, two crops of early-maturing hemp can be grown yearly, or a crop of hemp followed by a crop of peas to maintain the fertility and condition of the soil. Farmers in India plant hemp after millet, rice, indigo, tobacco, or coriander. Extensive experiments have shown that hemp is the best green manure for wheat.

Lyster Dewey suggested this scheme of crop rotation for hemp:

1st Year	2nd Year	3rd Year	4th year	5th Year
Hemp	Corn	Wheat	Clover	Grass
Hemp	Sug Beet, Potato, Onion	"	"	"
Corn	Peas, Beans	Hemp	Barley, Oats	Clover

1st Yr	*2nd Yr*	*3rd Yr*	*4th Yr*	*5th Yr*
Hemp	Corn	Wheat	Clover	Grass
Hemp	Sug Beet Potatot, Onion	Wheat	Clover	Grass
Corn		Hemp	Barley, Oats	Clover

S.S. Boyce gave more details in his book on *Hemp*(1900):

"The rotation kept up by rye or vetch, hemp, peas, and again rye, gives as perfect a condition of soil as can be desired. The roots of the hemp decay early, the peas penetrate deeply and leave the soil porous and supplied with nitrogen and humus; while rye and vetch keep the soil employed, and the three furnish feeding material more than paying their cost, while the rotation prevents any cloying of the soil appetite." **(20)**

A failed crop of hemp can be left to mature and then be burned, but better results will be obtained if it is plowed under as soon as it is certain that the crop is inadequate for fiber production. They rot very slowly, so mature stalks and hurds should be burnt rather than plowed under.

Hemp prefers alkaline soil, and it will not grow well on soil that previously was overgrown with either sedges or huckleberry bushes (indicators of acidic soils).

Cannabis is one of the best crops for eradicating weeds because it grows so quickly and suppresses their growth with its secretions of caffeic, ferulic, benzoic and coumaric acids. When hemp is planted in a fallow field, it destroys sowthistle, quack-grass, and cord-grass. Thus it becomes possible to grow two or three grain crops following hemp, whereas after ordinary summer-fallow, the second crop of grain usually is badly infested with weeds. The obnoxious bindweed is held in check by hemp, but the vines must be removed before the hemp goes to seed. Wild morning glory and bindweed vines will climb up hemp stalks.

No herbicides are needed when the spacing is 16 inches or less, because the rapid growth of hemp will suppress the weeds. With wider spacing, herbicides may be required. Dr. Ivan Bocsa recommends that monocotyledons be suppressed with Benefin (1 gal/acre of a 20% solution), applied with disc before sowing. Dicotyledons can be fought with Maloran (50%, 3 lb/acre), Patoran (2 lb/acre), or Pyramine (5 lb/acre), applied immediately after sowing. **(16)**

When hemp is cultivated for seed, Canada thistles may appear among the stands and must be spudded out manually while the hemp is only a few inches high. Canada thistle and quackgrass can be killed completely by one crop of hemp.

Cannabis is damaged by broomrape (*Orobanche ramosa,* chokeweed), a very short plant with yellowish leaves and dull purple flowers. Its seeds stick to the calyx of hempseed and thus are transmitted. Broomrape is parasitic on the roots of hemp, killing the host before it can mature. Broomrape invades when the soil has become exhausted, or "hempsick" through neglect. It is prevented by crop rotation and by clean seeds. An application of calcium carbide to the soil in the fall effectively destroys broomrape seeds.

Ammonium nitrate and sulfate will drastically reduce broomrape infestation, but these fertilizers also will affect crop yields. Trisodium phosphate can be combined with ammonium sulfate for greater effect. **(21)**

Cannabis protects potatoes from late blight by *Phytophtora infestans*. When potato tubers are soaked in a solution of kansatin (extracted from hemp leaves), their germination is increased, the sprouts are longer and weigh more, and infestation by *Corynebacterium michiganense* and *C. sepedonicum* is reduced. Infection by stem nematode also is lowered considerably. Extracts of cannabis effectively reduce the incidence of the nematodes *T. brassicae*, *H. indicus*, and *R. reniformis*, and *M. incognita*. The whole plant and leaf extracted in water is generally effective against insect pests.

When treated with hemp leaf extract, tomato seeds increase their germination by 17% and their yield by 33%. **(22)**

When beans are grown together with hemp, the beans will not become infested with brown spot. Hemp is effective against infestation of asters by *Fusirois*, and it protects sugar beets from turnip fleas, and cabbages from white cabbage butterfly. Cannabis also guards peas from pea aphis (*Acyrthosiphon pisum*). Hemp purges may-beetle (*Melontha*) from the soil. Weevils cannot become established in granaries where hemp has been dried.

C. Kok, *et al.*, have shown that the major soil pathogens *Verticillium dahliae* (fungus) and Columbian root-knot nematodes (*Meloidogyne chitwoodi* and *M. hapla*) are strongly suppressed by hemp. Some agronomists suggest that soybeans grown in rotation after hemp shows a significant decrease in soybean cyst nematodes.

Bee breeders use hemp as a pollen insulator; no other plant is so effective as a hedge against pollination.

2.7 ~ Diseases & Pests

During World War II, all hempseed distributed by the USDA was treated with mercury compounds (i.e., ethyl mercury phosphate); these seeds yielded an average increase of 16% in the emergence of plants, up to 100% increase over untreated seeds in some instances. This was the first time that the entire national supply (33,000 bushels) of seed of an important crop was treated for protection against microorganisms.

Cannabis is afflicted by over 100 diseases caused by fungi, bacteria, viruses, nematodes, plants, and abiotic challenges (genetics, nutrients, stress and pollutants) but only about a dozen cause serious problems.

With the exception of striping virus, the most common diseases of hemp (i.e., *Hypochnus solani* and *Pythium sp.*) can be controlled by treatment of the seeds with Clorox (25% sodium hypochlorite) diluted with an equal volume of water and adjusted to pH 9. Soak the seeds for 10 minutes, then rinse thoroughly with fresh water. **(24, 25)**

Cannabis' resistance to diseases and pests can be strengthened by the judicious use of methyl salicylate, which is a major component of wintergreen oil. Aspirin (acetyl

salicylic acid) also is effective. Dissolve two tablets in a quart of water and apply the solution as a foliar spray.

Fungi & Bacteria --- More than 90 species of fungi attack Cannabis. Seedlings can be infected by damping-off fungi; the flowers and leaves are vulnerable to grey mold, yellow, brown and olive leaf spots, mildew and brown blight, pink rot, and viruses. The stalk and stems are susceptible to attack by grey mold, hemp canker, *Fusarium oxysporum* canker and wilt, stem nema, charcoal rot, anthracnose, and striatura ulcerosa. The roots can be diseased by *Fusarium*, rhizoc, sclerotium root rot, and nematodes. *Alternaria alternata* Keissler, a common fungal pathogen of many plants, can destroy up to 45% of hempseed in a crop.

K. Roder investigated hemp diseases, and isolated 7 strains of *Sphaerella cann.,* 13 strains of *Phoma* or *Phyllosticta*, and 13 forms of *Phomopsis, Coniothyrium, Vermicularia, Fusarium*, and *Cylindrocarpon*. None of these species can infect the roots of hemp directly, unless the roots are weak or injured.

Gray mold (*Botrytis cinerea*) and hemp canker (*Sclerotina sclerotiorum*) can severely damage a hemp crop in wet years. In temperate regions with high humidity and low temperatures, botrytis can completely destroy a hemp crop within a week. Botrytis and hemp canker can be controlled by spraying alternately with the fungicides vinchlozolin (0.5 kg/ha) and iprodion (0.5 kg/ha) at two-week intervals from June through August. Tetramethylthiuran disulfide also is effective. Van der Werf, *et al*., however, found from three years of field experiments that one or two applications did not increase actual stem yield. They concluded that, "although fungal diseases may severely reduce hemp yield in the Netherlands, the use of fungicides is not worthwhile". They recommended breeding cultivars less susceptible to *B. cinerea* in particular. Botrytis can be controlled by applications of sulfur followed by "AQ-10", a microbial product. Bentonite clay also can control botrytis; it is better to use California calcium-bentonite rather than the more common sodium variety. Potassium bicarbonate ("Kali-Green") also kills botrytis. **(26)**

Botrytis appears as "damping-off" (moldy germination) on seedlings; it can be prevented by aeration of the soil, by hydrogen peroxide, or by the Burgundy Formula. Dissolve 1 lb of calcium sulfate and 1 lb of washing-soda crystals in 10 gallons of water. Soak the seeds in this solution, then rinse with fresh water.

The Chestnut Formula also prevents damping-off. Mix 2 parts copper sulfate and 11 parts ammonium carbonate in a glass jar. Dissolve 1 oz in 2 gallons of water. Soak the seeds in this solution, then rinse them with fresh water.

Botrytis is a stem disease in fiber cultivars, arising as a gray-brown mycelial mat, later covered with conidia. The stem becomes chlorotic along the edge of the mat, then reduces to soft, shredded cankers; the plant often snaps at that point, or wilts above it. The mature floral bracts of female drug cultivars are most susceptible to infestation. Leaflets turn yellow, then wilt, and pistils become brown. Mycelia envelope the infloresences, which dissolve into gray-brown slime.

Infection by *Botrytis* is directly affected by the level of calicum in the plant; the higher the amount of Ca, the lower the incidence of *Botrytis*. Sprays of Ca-silicate (2,000 ppm)

and Ca-formate (2,000 ppm) provide effective control of fungi and are safe alternatives to highly toxic fungicides.

Damping off is caused by other several fungi, mostly by the Protoctistan oomycetes *Pythium aphanidermatum* and *P. ultimum*. Other causative fungi include *Fusarium solani*, *F. oxysporum*, *F. avenaceum*, *F. graminearum*, and *F. sulpurem, Rhizoctonia solani*, and *Macrophomina phaseolina*.

The severity of infection by facultative parasites is affected by the levels of nitrogen and potassium; low N and high K provide resistance; high N and low K invite parasites.

Wilt is caused by *Fusarium oxysporum* f. sp. *cannabis* Nov. & Snyd. It first appears on 3-month old plants as a yellowish-green color and small dark spots on the lower leaves, which die but remain hanging. The plant may bend to the side of the stem that is affected.

In 1999, Ag/Bio Con, a Montana company, offered the world a mutant strain of *Fusarium oxysporum* as a mycoherbicide against cannabis --- an utterly insane promotion that has instigated lawsuits to cease and desist. *Fusarium* mutates very easily and spreads to other crops. It is an environmental disaster.

Verticillium wilt is caused by *Verticillium*(two species); *Macrophomina phaseolina* causes premature wilt (also known as charcoal rot).

Hemp twig blight is caused by *Botryosphaeria maronii* (Cav.) Charles & Jenkins. The leaves quickly wilt and droop and turn brown, but remain attached. The symptoms first appear on the tips of branches. The lower parts become bleached.

Two species of *Colletotrichum* cause anthracnose in cannabis.

Hemp canker, caused by *Sclerotinia sclerotiorumi,* is one of the most important diseases of cannabis. It appears as wet lesions on the branches of plants as they mature; the lesions become dark cankers. The pith fills with white mycelia. Black sclerotia then develop in the stem and in the pith. The plants wilt and collapse. The optimal temperature range for its growth and maturation of is 24-33^{o} C. *Sclerotinia* can be controlled somewhat by proper drainage of the fields.

Yellow leaf spot is caused by two species of *Septoria*; brown leaf spot is caused by species of *Phoma* and *Ascochyta*; *Phomopsis ganjae* causes white leaf spot.

Severe leaf infections also are caused by strains of *Sphaerella* (stem browning)*, Phyllosticta, Cercospora*, *Microdiplodia, Macrosporium cann.*, and *Pseudoperonospora* (olive leaf spot), and *Didymella arcuata*. **(32)**

Didymella arcuata is found in association with the fungus *Ascochyta cann.* Lasch. The optimal temperature for the germination and growth of *D. arcuata* is 19-26^{o} C. Its sporulation is promoted by light; its vegetative development is stimulated by darkness. **(33)**

Leaf spots caused by *Cercospora cannabis* Hara & Fukui are yellow-tan or brown. They are circular at first but become irregular and distinct.

Trichothecium roseum causes pink rot on cannabis drug cultivars in greenhouses.

Hemp rust (*Melampsora cannabina*) appears as orange patches on the leaves. It can be controlled by spraying with thiocarbamate.

Bacteriosis (stripe disease) is caused by *Pseudomonas cannabina* Sutic & Dows. var. *italica* Dows. Scattered reddish-violet spots (under 2 mm), surrounded by a pale yellow halo, appear on leaf blades, followed by rapid shedding. Small necrotic elongate cavities, filled with bacteria, appear on the stems.

Some less common but nonetheless virulent diseases of cannabis are anthracnose (*Colletotrichum atramentarium*) and brown blight, which is caused by species of *Alternaria* and *Stemphylium*.

Many of the bacterial and fungal diseases of cannabis and other crops can be controlled by applications of Bacillus subtilis, which is available in several commercial products (i.e, Serenade, manufactured by Agraquest).

Several bacteria that are pathogenic to humans have been found on Cannabis, including: *Salmonella muenchen*, *Klebsiella pneumoniae*, *Euterobacter cloacae*, *E. agglomerans*, *Streptococcus* (Group D), *Thermoactinomyces candidus*, *T. vulgaris*, *Micropolyspora faeni*, *Aspergillus fumigatus*, *A. niger, A. flavus*, *A. tamarri*, *A. sulphureus*, *A. repens*, *Penicillium chrysogenum*, *P. italicum*, *Rhizopus stolonifer*, *Alternaria alternata*, *Curvularia lunata*, and *Histoplasmus capsulatum*. *Aspergillus* can be killed by baking cannabis at 150^{o} C for 15 minutes, but only about 15% is destroyed by smoking through a waterpipe. Microbial pathogens and toxins, however, are not destroyed by heating or other methods of sterilization.

Insects --- Several species of mites are injurious to stored hempseed: *Tyroglyphidae* (3 sp., especially *T. farinae*), *Glycyphagidae* (6 species, especially *G. destructor*), and predaceous *Cheyletus eruditus*. The maximum number of mites are found in July-August. *T. farinae* occurs constantly. Once introduced into storage, the mites can persist for several years. *Tyrophagus* can be controlled by treatment of the seed with fungitoxic preparations (i.e., Panogen and Aldogen). The mechanical damage of hempseed stimulates the breeding of mites. The miticide "Cinnamite" (cinnamaldehyde), produced by Mycogen, is very effective. **(23)**

Spider mites also plague hemp. Their effect is seen as minute white spots on the top of leaves. The mites appear as tiny black specks on the the underside of leaves. They can be controlled by introduction of another mite, *Phytoseiulis persimilis*.

The seedlings can be attacked by hemp flea beetles, cutworms and white grubs. The stalks and stems can be infested by European corn borers and hemp borers, weevils, and by modellid and longhorn grubs. The larva of the Death's Head moth (*Acherontia atropos*) occasionally bore into hemp stalks. Flea beetles, white root grubs, wireworms, fungus gnats, root maggots, termites and ants will attack the roots of cannabis.

The click beetle (*Agriotes mancus*), also known as wireworm in its juvenile form, infests the top six inches of soil and eats the roots of plants, including cannabis. Wireworm can

be controlled by introduction of beneficial nematodes (*Heterohabidis* and *Steinernema* spp.).

Marijuana thrips (*Oxythrips cannabensis Knechtel)* is a sucking insect that is host-specific to hemp. Common thrips (*Frankliniella occidentalis*) eat the calyx of cannabis, causing deformation and affecting viability. Thrips can be controlled by the predators *Amblysieus cucumeris*, *A. degenerens*, and *Orius tristicolor*. The aphid *Phorodon cannabis* Pass. also is found on hemp.

The tarnished plant bug (*Lygus* spp.) has been found on hemp crops throughout Canada It feeds on the apical meristem, which appears malformed and stunted. Brown lesions are visible on the stem where the pest has been feeding. It can be controlled by the predatory Spined Soldier Bug (*Podisus* spp.).

The hemp flea beetle (*Psylliode attenuata*) hibernate in the soil until the temperature of the soil and air rises to 10^{o} C (50^{o} F). Then they emerge and feed on leaves and stems of seedlings. The pest can be controlled by planting 'bait' hemp with sodium fluosilicate (15 kg/ha) one month before the mass planting of the crop. The bait plants are treated again after 10 days. This procedure reduces the number of hemp fleas by 90%. In rare, extreme cases, methyl parathion can be used (50% solution, 8 fluid oz/acre).

The larvae of hemp borer moths (*Grapholita delineana*) damage the stalks to such extent that the quality does not meet the industrial standard. Up to three generations can develop each year. The caterpillars live in the stems and flowers of female plants, where they damage developing seeds (50% or more). After feeding, the caterpillars burrow into the soil and overwinter there. In Hungary, where they were first observed, the period between August 20 and September 7 (when daylight is reduced from 15 to 14 hours) is critical for diapause of the larvae. An earlier harvest will prevent the overwintering of most of the larvae; thus the population of the next year can be considerably reduced. **(27)**

The borers can be fought with 50% methyl parathion (20 fl oz/acre). After harvesting, the stubble and waste stalks should be burned, and the field plowed. Organophosphate insecticides are much more effective than organochlorine compounds. Treatment methods vary according to the intended use of the crop (fiber or seed). Two or three applications of Fenthion (500 gr/ha) are up to 98% effective. **(28)**

The wasp *Trichogramma evanescens* Westw. parasitizes the eggs of the hemp moth; 80,000-120,000 wasps/ha are released at one time. Biological control is more efficacious than of chemical methods. Several Hymenoptera species of parasites and predators will prey on *G. delineana*. Commercially available Persimilis (*Phytoseiulus persimilis*) will destroy spider mites that infest cannabis (See Appendix 1, #34). **(29)**

The European corn borer also damages hemp crops. The hemp greenfly (*Phorodon cannabis*) can damage fiber hemp, but it has never been a major problem.

The most common rootknot nematode, *Meloidogyne incognita*, occurs on fiber cultivars of cannabis. The northern rootknot nematode (*Meloidogyne hapla*) has appeared in European hemp fields in recent years. Nematodes can be controlled somewhat by planting resistant varieties of cannabis, and by applications of aqueous extracts of several common plants (i.e., pigweed, marigold, hyssop and mustard). Aqueous urea is very

effective against nematodes, but it must be buffered to prevent damage to the plants. Lesion nematodes (*Pratylenchus spp.*), reniform nematodes (*Rotylenchus spp.*), and spiral nematodes (*Helicotylenchus* and *Scutellonema spp.*) also have been found in hemp crops.

The hemp sawfly (*Trichiocampus cannabis* Xiao et Huang) is one of the main pests of hemp in China. The larva feeds on hemp leaves, making many holes. It produces two generations/year, and the mature larvae overwinter in the soil. The sawfly is controlled by Fenitrothion.

The leaf roller moth (Tortricidae, *Grapholitha zinana*) can damage up to 100% of hemp sowings. The larvae damage the infloresences and seed. N. Kozinets, who discovered the pest in 1964, advised spraying hemp sowing with DDT (15-20 kg/ha) during the flight of the adult moth. **(30)**

Irrigation too early and continuing humid conditions will promote mass attack of hemp stems by *Pyraustis nubialis* Hb. The fiber yield from attacked plants deteriorates by one grade. The pest can be controlled by introduction of *Trichogramma*. The number of caterpillars can be reduced by over 60%, and plant damage decreased by 80%. **(31)**

Cannabis foliage and infloresence possesses phytocidal activity. The antibacterial properties are effective against *Bacillus mesentericus, B. subtilis, B. mycoides, B. cereus, Micrococcus albus, M. aureus,* and *Clostridium welchii*. Hemp is inactive against *Salmonella*, *Pseudomonas*, *Azotobacter*, and *Candida*. The maximum inhibitory effect from leaf extracts occurs in August; the flowers are most potent in September, after which time there is a marked decline in activity. Phosphate fertilizer promotes the antibacterial activity, whereas K- and N-fertilized plants are less active. **(34)**

2.8 ~ Nutrients

The general nutrient requirements of hemp can be satisfied with generous applications of manure. Cottonseed is considered to be a perfect fertilizer for hemp, and holds moisture and mechanically prepares the soil. It is applied at the rate of 500 to 1,000 lb/acre while plowing in autumn. If the preceding crop was soybeans or cowpeas, then 500 lb/acre is sufficient.

S.S. Boyce gave these recommendations for fertilizing hemp:

"An application of 200 pounds of bone-meal in November has the effect to warm the soil and hasten germination where hemp is sown early, and to stimulate the hemp to a quick, early growth, before it comes to assimilate the coarser foods, and to give an increase of a foot to a foot and a half in growth...

"Cotton seed and farm manures of equal proportions, with an addition of 10% of acid phosphate, [can be] applied according to the condition of the soil. The only other addition to the compost of 1,000 pounds of cotton seed, 1,000 pounds barn manure and 200 pounds of acid phosphate, would be 250 pounds of ammonium sulfate [per acre]... This would only be required upon old, exhausted cotton lands, while this amount would be sufficient for 4 or 5 acres, according to fertility, and for 10 acres, provided a crop of cowpeas broadcast had preceded."

Steep-water in which hemp has been retted contains: C (55.66%), H (8.21%), N (6.45%), O (29.68%). R. Antoniu, *et al.*, reported that it makes a valuable fertilizer :

"The wastewaters from hemp retting may be used for irrigation without presenting the danger of polluting the phreatic waters with organic substances because these substances are nearly totally retained on the filtration field. The chloride content of the raw wastewater indicates small quantities that could not produce the soil salinization after irrigations. In the phreatic water below the experimental field, the chloride content is 10-fold reduced. While the waste water is acid, the water under the filtration and irrigated field has a neutral or slightly alkaline reaction. Wastewaters were utilized for the irrigation of seed corn, silo corn, sugar beet (furrow irrigation), and alfalfa. For irrigated seed corn there was an increased production (139-143%) in comparison with the non-irrigated. For silo corn increases varied between 133-177%, for sugar beet between 176-183%, and for alfalfa, 107-416%. For all cultures the irrigation norm varied between 2,250-3,550 m^3/ha."

I. Popescu and I. Afusoae reported this finding from their study of retting:

"Fermentation can help turn hemp boon [hurds] into a suitable product for soil fertilization. During fermentation the boon reaches almost the same level of assimilable N, K, Mn and Cu as in barnyard manure."

If NPK fertilizers are used, it is necessary to know their proper amounts, effects and relationships. These considerations are determined by the class of soil in which the crop is grown, and the nutrient content of the soil.

Fertilizers cause changes in basic soil properties and hemp yield. N.Gorodnii conducted experiments with this problem. He cultivated hemp on two types of loam with 6 variants of nutrients (without fertilizers, with 20, 40, and 80 tons manure/ha/year, with NPK calculated on 40 tons manure/ha, and with N 12:P 90:K 60):

"With continuous cultivation of hemp on a background of ammonium sulfate, superphosphate, and sylvite, the total absorbed bases in the soil, the rate of Ca saturation, and the nitrification ability were decreased, saturation of the absorbing complex by N and NH_4 ions and the exchange and hydrolytic acidity of the soil were increased: the physical properties of the soil deteriorated, the density increased and the percentage of water-resistant aggregates decreased. Applying mineral fertilizers during the first years increased the hemp seed yield 100%, in comparison with the same doses of manure. Application of manure, in comparison with the same doses of mineral fertilizers, increased the weight of common hemp 2-3 fold. **" (35)**

The nutrient uptake by cannabis reaches it maximum just before maturity and blossoming. Nitrogen and phosphorus uptake then increase up to 250%, and potassium requirements increase 400%. The uptake of calcium and magnesium increases 150%. Additional amounts of nutrients must be readily available to the plants at that time in order to produce maximum yields. Hemp consumes about 1 kg of nutrients for each kg of fiber it produces. At least twice as much nutrients must be available than will be removed from the soil by the harvested plants. If hemp is field-retted, nearly half of the nutrients are returned to the soil.

The 1897 USDA *Year Book* listed the amounts of fertilizing elements required to produce 100 pounds of hemp fibers from 600 lb of plant weight: N (6.27 lb), KOH (10.13 lb), H_3PO_4 (3.32 lb). For a yield of 1,500 lb of fiber/acre (9,000 lb of growth), the nutrient requirements would be: N (94.05 lb), KOH (151.95 lb), and H_3PO_4 (49.8 lb).

Fertilizer trials conducted on six soil types at the Iowa Agricultural Experiment Station (1942-43) gave these results:

Where N (25 lb/acre), P (50 lb P_2O_5), and K (25 lb K_2O) were applied singly and in combinations, average increases in acre yield of dry, rettted straw from fertilization ranged from 0.37 to 0.90 ton, P from 0.12 to 0.80 ton, and K from -0.32 to +0.25 ton N at 100 lb/acre produced substantial yield increases over N at 25 lb, which was not enough for maximum yields. Response to P was limited by N deficiency in a number of cases. N-P combinations produced higher yields than did either N or P or PK. In general, K did not increase hemp yields, [which] were usually highest on soil types which contained the greatest quantities of N and organic matter, provided drainage was adequate. **(36)**

Commercial hemp farmers in the temperate zones of Europe generally use a nutrient ratio of 2N:1P:4K. In hot, sunny, and tropical climes, hemp uses less potassium, and a ratio of 2N:1P:2K is more suitable. In areas having a winter or monsoon season, more K and less N is required, so the ratio 2N:1P:3K is used.

Other reports state that a high yield of fiber is obtained with about 160 kg N, 110 kg P, and 90 kg K per hectare. The highest quality bast fiber reportedly is obtained with about 70 kg of P and 60 kg of K per hectare, followed by a later dressing of 90 kg N, 70 kg P, and 60 kg K/ha. This also yields a 100% increase in fiber content in comparison to other NPK ratios. Canadian hemp farmers have applied N at 120 kg/ha, P at 100 kg/ha, and K at 160 kg/ha. M. Molina, who cultivated hemp for 13 years in Italy, stated:

"Fertilization with 300 kg of ammonium sulfate or 450 kg of dried blood, 500 kg superphosphate and 150 kg K-sulfate per hectare is recommended." **(37)**

Dr. Ivan Bocsa summarized the NPK requirements of hemp thus: Class I (rich soil) requires 16-43 lb N/short ton of stalk yield, 8-24 lb P/short ton, and 7-24 lb K/short ton. Soil Classes II and III require 20-46 lb N/short ton, 14-34 lb P/short ton, and 8-27 lb K/short ton.

G.R. Bedak tested the effectiveness of periodic and annual applications of fertilizers in a hemp-hemp and hemp-corn crop rotation. The application of P and K fertilizers every two years does not affect the quality of fiber, and the cost of storing, transporting and applying fertilizers are about 23% less than for annual application. **(38)**

L. Dobrounof reported these findings from his studies of critical periods in the mineral nutrition of hemp:

"There is a long period during which a given nutrient exerts its influence... Beginning when the hemp plant is 6-12 days old, it lasts (in relation to the fiber) in male plants 22-28 days (i.e., until the beginning of flowering) and in the female plants 32-38 days (i.e., until flowering is complete). Within the period, there exists a short critical period during which the mineral nutrition exerts its greatest influence on the direction and intensity of

vegetative and reproductive development. In male plants this period is 4-5 days before the buds are completely formed, while in female plants it is the 8-10 days at the beginning of flowering. At the beginning of the period of effective action is the stage when the plant is passing from nutrition at the expense of the seed to independent root nutrition. This stage lasts 4-6 days and begins when the plants are 6-8 days old. **(39)**

N--- Approximately 100-150 kg N/ha (and 80-100 kg P/ha, and 100-180 kg K/ha) is required to obtain 10 tons of stems/hectare (10 kg N per ton of dry stalk).

Though the stem yield is high, the quality of fiber decreases with increasing amounts of N. Under low-light conditions, ammonium sulfate or nitrate stimulates stem growth. The absorption of N is most intensive from 20-25 days after germination. **(40-46)**

Cannabis is nitrophilic, but if the plant is grown for its resin, the supply should be kept under 400 ppm, and it must be reduced to about 100 ppm during flowering. The application of N should be reduced 20% in very hot weather.

The Russian agronomist B. Lesik showed that the form of N substantially affects the growth of hemp and the quality of its fiber:

"When ammonia N was applied, the plants passed through their development cycle more rapidly. The stalks were thinner and there was less development of wood. In comparison with nitrate N, ammonia N caused increases in the yield of long fibers, in the length of the elementary fibers, in flexibility, tensile strength, and uniformity of the fibers, and cellulose content, and there was a decrease in the amount of waste fibers. The retting process also proceeded more quickly, and a smaller amount of extractive substances (organic acids and N) accumulated in the retting fluid. Fertilization with the mixed form gave intermediate results. The thinness of the fibers did not depend on the form of N applied". **(47)**

High N has a "masculinizing" effect on the hemp phenotype; it stimulates the formation of male flowers. The proportion, degree, and number of monoecious flowers increases with increasing N, and the total N content is always higher in monoecious plants than in females, whatever the dose of N. **(48)**

Excessive N causes hemp to grow rapidly as seedlings, but the plants wilt, turn to copper-brown, and die when they begin to flower. High levels of N in the middle of the growth cycle will cause water uptake to increase, and induces a sex ratio as high as females 9:1 males. An excess of N is indicated by abnormally large, pulpy branches and veins, with few flowers. The stem turns brown, and terminal shoots stop developing. Leaves are spotted with dead areas, and they curl, pimple, and turn yellow between veins. The breaking strength of the fibers is reduced by about 15%. The stem texture is herbaceous with a hollow pith and short internodes. Excess N added during preparation of the soil inhibits stem development. Best results are obtained by adding half of the required N in the primary treatment, and the second half at the first feeding.

If the initial growth of a hempfield is slow, it can be aided by a foliar spray of 20 kg of urea in 400 liters of water/ha. The addition of ammonium sulfate or nitrate with sulfur before blooming occurs will increase the growth rate considerably. Ammonium nitrate is more effective than the sulfate. Sodium nitrate gives good results, but the quality of fiber

is poor. Cannabis is very sensitive to chlorine; therefore, sulfate salts are recommended over chlorides or nitrates.

A deficiency of N causes the entire hemp plant to turn yellow (chlorosis) within a week. Lower leaves curl and shrivel, and veins turn purple. Stems are abnormally small and hollow with a woody pith. Growth and flowering are retarded, and the plants are mostly male. **(49)**

K. Tulaikova found bacterial cycles in the N metabolism of hemp:

"The requirements of hemp for abundant nitrogen fertilizers were found to be related to the development of numerous and diverse rhizobia on its roots, mainly ammonifying bacteria. During the germination stage, the bacteria are parasitic because they utilize not only the root excretions of plants but partly also the plastic matter which is being transported from leaves to roots. This is demonstrated by the weak development of the root during the first half of the growth period. If N feed is abundant, the relations between the hemp and bacteria are symbiotic... Simultaneous feeding on nitrates by both root bacteria and hemp induces N deficiency in the plants. Therefore, nitrate fertilizers are especially required for hemp development... An improvement in N status observed after bacterization with silica bacteria was probably due to the ability of the latter to fix atmospheric N." **(50)**

There are differences in the root microflora of hemp according to sex. Ammonifying and denitrifying bacteria which decompose organic P predominate on the roots of females, and greatly depend on the food reserves in the soil. Deficiency of soil nutrients increases the concentration of microbes on the roots; thus the number of ammonifying bacteria is much less on the roots of hemp grown in rich soil than in the roots of plants grown in exhausted soil. Silicate bacteria predominate on male roots, which absorb N and K more vigorously than the female up to the flowering phase. **(51)**

P --- Hemp growth, fiber yield, and concentration of THC are positively correlated with extractable phosphate. Cannabis uses 250% more phosphorus at flowering than during the vegetative phase. A deficiency of P shows as abnormally dark dull green leaves with a purple tint on the underside, and downward-curled margins. The stem gradually turns reddish, then black. The roots are long, with few laterals. The plants are slow to mature and set seed.

P. Gorshkov studied the peculiarities of P nutrition for hemp:

"To obtain high yields of hemp, it is necessary to assure the plants an easily accessible source of phosphoric acid by applying granulated superphosphate at the very beginning of development, before the plants have reached the phase of 6 pairs of leaves. At later phases of development the requirement for P may be met by soil P and by less soluble forms of P fertilizer." **(52)**

The Russian agronomist M. Khann confirmed the beneficial effect of superphosphate drilled in with hemp seeds:

"This method allowed for a 3-fold decrease of the superphosphate without lowering of the productivity. The increase in the yield of fiber obtained from 1 kg P_2O_5 drilled in with

the seeds exceeded by 3-6 times the corresponding increases from broadcasting 1 kg P_2O_5. The corresponding seed yield increase was 3.5-4.7 times higher." **(53)**

K --- Either potassium sulfate or potash is recommended over KCl because the chloride ion interferes with fiber development. The combination of potash with manure increases yields up to 30%, and increases the availability of phosphorus by almost 200%. A combination of potash, Mg-sulfate and manure produces the greatest yield, increasing with higher levels of Mg. Potash strengthens the stalk and stems and increases the resistance of hemp to broom rape. The absorption of K is most intense in the 4th week after germination.

Additional K increases plant height, thickens the stem, and produces heavy, large, dark green leaves. The growth cycle is shortened by about one week, and the sex ratio is stabilized at about females 7:3 males. An excess of K after the 10th week, or when flowering occurs, will delay maturity and inhibit resin production. White spots appear on leaves, meristematic growth ceases, and the stem is woody and hollow. When cannabis is cultivated for resin, the supply of K should be reduced by 50% during flowering.

I. Berzak reported these results of his experiments on the effect of various K fertilizers on the yield and quality of hemp fibers:

"The highest yields of stems and fibers were obtained with kalimag (K-sulfate/Magnesia/Mg-sulfate), and with K-chloride/K-sulfate mixture, whereas the lowest was obtained with kainite (K-chloride/Mg-sulfate). Male hemp responded to K fertilizers much more than female hemp". **(54)**

Potassium deficiency is indicated by coppery mottling and curled, grey edges or a brown margin on leaves, followed by dark spots and bleaching between the veins. The symptoms first appear on bottom leaves. Old foliage turns dark gray, and new leaves turn yellow and die. Growth is retarded, and the roots and apical meristems turn pale yellow. The stem is herbaceous, and hollow in males, while females are solid. Deficiency can occur in acidic soil or in low-light conditions. The addition of a little detergent will increase the wetness of the nutrient solution and allow K to be more easily absorbed.

When K is deficient, transpiration is reduced, but water consumption is increased, especially in young plants. A deficiency of K decreases the yields of stems and fiber, but contributes the formation of strong, elastic fibers. **(55)**

Ca --- Calcium gives cannabis very strong, fibrous, short stems with dark green leaves and swollen flowers. An adequate supply is vital in the 6th-9th weeks of growth. The largest absorption of Ca is made possible when calcium carbonate is applied together with small doses of humus. **(56)**

Calcium-deficient plants are stunted, weak and flabby. Terminal buds die, and the stem becomes brittle and covered with dark areas. Upper leaves are darker than usual, yellow at the edges, and they crinkle, dry up, and fall off. Any new leaves that form will die. Brown and white spots appear on lower leaves.

Excessive Ca will stunt the early growth of cannabis, and causes terminal shoots to be weak and under-developed. Foliage is less abundant, and blackening occurs around the

veins. The stems are fibrous and woody, with a hollow pith. The sex ratio changes to males 7:3 females.

Calcium affords plants considerable resistance to infection with *Botrytis*; the higher the level of calcium, the lower the incidence of *Botrytis*.

Trace Elements --- Micronutrient deficiencies often are caused by alkaline water, which prevents uptake by plants. Such deficiencies usually can be covered by the use of commercially available "transplanting solutions" and by adjusting the soil to neutral pH.

Mg --- Cannabis is very sensitive to magnesium deficiency, which is likely to occur in sandy soils and during seasons of heavy rainfall. Chlorosis begins on the bottom leaves. Grey-white patches, varicose veins, and yellow margins appear on the leaves, which curl and die on the edges. Growth is stunted, the stem is thin, and leaves drop off. The stem texture of males is woody, and females are herbaceous. The pith is hollow. A deficiency can be corrected with Mg-phosphate and brine (1 quart per 100 lb of compost), or with Epsom salts.

Hemp has an extraordinarily high requirement for Mg, and is exceptional in comparison to most other plants, which are killed by applications of Mg alone. Combinations of K and Mg give the highest yields, which increase considerably with an increase in the Mg. **(57)**

A. Haraszty conducted experiments for 10 years to augment the yield of hemp fiber with macro- and micronutrients (tested in over 50 combinations). He found significant effects with formulations containing K, Mn and Mg (applied in the form of their sulfates at 10 kg/ha), by which he achieved up to 32% increases in fiber quantity. The combination of K and Mn gave a 17% increase. **(58)**

Fe --- The symptoms of iron deficiency are the same as for magnesium, but they appear on the upper leaves first. Acidic soils dissolve and chelate iron, making it unavailable to plants. Powdered magnetite (magnetic iron oxide) will supply sufficient Fe, and it stimulates plant growth by the effect of magnetic energy. 10 ppm of Fe gives the best growth of hemp fiber; 5 ppm gives the best yield of cannabinoids.

C. Olsen studied Fe absorption by hemp in hydroponic beds:

"When hemp is cultured in solutions low in Ca and with Fe-sulfate as Fe source, increasing growth inhibition due to Fe intoxication is observed when the pH of the solution decreases from 6 to 4. This is due to the fact that the ferric ion concentration in the solution increases greatly when the pH is lowered to 4. The same is true in soil. Even so, hemp can develop quite normally in solution of pH 4 provided the Ca ion concentration is high, resulting in a sufficient lowering of the rate of Fe absorption to preclude intoxication. This antagonistic situation does not occur in nature since soil of low pH and high Ca concentration does not exist." **(59)**

Mn --- A deficiency of manganese will stunt the growth and flowering of hemp. Leaves appear mottled with grey-brown necrotic spots. The plants lack vitamin C; there are some deaths. Signs of deficiency first appear on shoots. Leaf margins remain green while the rest of the leaf turns yellow or white.

S --- Sulfur stimulates root growth and seed production. S-deficient hemp is pale green, with purple veins. The stem is stiff, woody, and thin; the seeds are immature.

B --- Hemp requires 250 grams of boron per acre. When sufficient P and K are available, an additional application of boric acid (1 kg/ha), Cu-sulfate (1 kg/ha), and Mn-sulfate (10 kg/ha) will produce a significant increase in yields and in the quality of fiber and seeds. A deficiency of B is revealed by cracked, stunted stems and dry rot. Leaves turn purple, terminal shoots curl and die, petioles become brittle, and the flowers are covered with dry areas. New shoots turn gray or brown and die with a burnt appearance. The situation can be corrected with a foliar spray of boric acid.

Cu --- Cannabis does not have a high tolerance for copper, but supplementary Cu-sulfate will improve the quality and yield of hemp, especially in peat, which often is deficient in this element. A deficiency causes stems to weaken and break. Treatment of a field with 10 kg/yoke (1.42 acres) will increase the fiber bundle diameter up to 15%; when the Cu is combined with cobalt, the bundle diameter will increase up to 23%.

Mo --- A deficiency of molybdenum is indicated by yellowing between veins on leaves. The middle leaves turn yellow.

Zn --- A deficiency of zinc is indicated by chlorosis between the veins at the base of shoots, and by the accompanying twist of leaf blades. Flowering is inhibited.

Over-watering produces symptoms resembling nutrient deficiencies or excesses. These usually can be corrected by reducing the water supply, or by drainage.

Table 2.3 ~ Symptoms of Nutrient Deficiency/Excess

Table 2.3
Symptoms of Nutrient Deficiency/Excess

LEAVES

Copper-brown (+N); Copper mottling (-K)
Curl (+N, -Mg)
Dead areas (+N)
Green, dull dark (-P); pale (-S)
Margins:
- Brown (-K)
- Curled, grey (-K)
- Downward-curl (-P)
- Yellow (-Ca, -Mg, -Fe)

New Leaves:
- Brown & white spots (-Ca)
- Chlorosis (-Fe)
- Dark (-Ca)
- Grey-brown & dying (-B)
- Grey-white spots (-Fe)
- Yellow edges (-Fe)
- Yellow & dying (-K)

Old Leaves:
- Chlorosis (-Mg)
- Yellow (-Mo)
- Dark-grey (-K)

Pimples (+N)
Purple (-B); Purple on underside (-P)
Spots:
- Grey-brown necrotic (-Mn)
- Grey-white patches (-Mg)
- White (+K)
- Dark (-K)

Twisted (-Zn)
Veins:
- Blackening around (+Ca)
- Bleaching between veins (-K)
- Chlorosis between veins (-Zn)
- Pulpy (+N)
- Purple (-S)
- Varicose (-Mg)

Yellow between veins (+N, -Mo); Yellow with green margins (-Mn)
Yellow-coppery areas, dying leaves (+Water)
Wilting (+N)

STEMS

Brittle (-Ca)
Brown (+N)
Cracked (-B)
Dark areas (-Ca)
Dry rot (-B)
Herbaceous (-K, +N, +K, +Ca)
Hollow females (-Mg); Hollow males (-K, +N, +K, +Ca)
Reddish, then black (-P)
Solid females (-K)
Weak, broken (-Cu)

MERISTEMS

Stunted (+K, +Ca, -Mn)

GENERAL GROWTH

Stunted, flabby (-Ca, -Mn, -B)

2.9 ~ Cultivating for Cannabinoids

According to a United Nations study, 5 factors are necessary for the "cultivation of Cannabis for a high resin production": (1) genotype, (2) photoperiod, (3) N-P-K, (4) at least 60-80 cm separation between plants, and (5) "optimal temperature of the ground at the time of sowing". Resin production is minimal at 44^{o} F (See also **2.5** and **2.10**).

The production of cannabinoids (THC, CBN, CBD, etc.) is greatly influenced by nutrients. As soil N increases relative to Mg, CBD increases relative to CBN. Increasing the ratio of N to Cu increases the level of CBD. Increasing amounts of P convert CBN to THC. Low to medium levels of P produces a high level of CBD, but CBD decreases with high levels of P. Low levels (levels less than 40 ppm) of Mg produce more CBD than do

high levels of Mg. As levels of Mg increase relative to Ca, the concentration of THC decreases. The concentration of Mg and Fe in leaves is positively correlated to THC levels. Potassium increases the concentration of CBN by effecting the dehydrogenation of THC. An excess of K in the 3rd month will inhibit resin production. Excess Ca will inhibit resin production, and it increases the production of CBD in the resin is produced. Either an excess or deficiency of Mg produces more CBD. 5 ppm Fe gives highest yields of THC.

The recommended "ideal" pattern of nutrient application for cannabinoid production is said to be: high N and K, low Ca, and medium Mg during the first 2 months of growth, continued high N and K, medium Mg, and increased Ca during the next 6-8 weeks, followed by decreased N, K, and Ca, and increased Mg through the flowering phase. Many growers use a commercial 15-30-30 formula throughout the season.

Mel Frank offers this micronutrient formula for high cannabinoid production: Fe-sulfate (5 mg/gal), Cu-sulfate (0.2 mg/gal), Mn-sulfate (2 mg/gal), Zn-sulfate (0.2 mg/gal), Boric acid (2 mg/gal), Molybdenic acid (0.1 mg/gal). Use 1 tspn/gal of nutrient solution, once monthly.

Bill Drake gives this recipe in *Marijuana: The Cultivator's Handbook*: Ca-sulfate (6 oz), mono-Ca-phosphate (4 oz), Mg-sulfate (6 oz), K-nitrate (8 oz), and Fe-sulfate (1 gr). Use 1 tspn/gal.

Many marijuana growers reportedly use a commercial 15-30-30 NPK mixture successfully throughout the growing season.

Since the 1960s, marijuana farmers have developed many special techniques to camouflage their operations and to enhance the production of psychoactive resin. Such cultivators grow the plant for its flowers rather than the fiber. They prefer to grow females because they produce more resin than males. The female is much larger and more vigorous than the male, which does not produce much foliage and dies soon after dispersing its pollen. What little resin the male does produce is, however, about as potent as that of the female, and it can be worth extracting and isomerizing. If the female is kept virgin so that seed production is prevented, it develops more flowers and more resin with greater potency. The mature virgin plant is called "sensimilla" (without seeds). For these reasons, the males are removed as soon as they can be identified.The cultivation of *bhang* (cannabis) is a highly ritualized process in India. Select seeds are kept in the mouth of a dead snake until they are sown under the waxing moon in July. Often a freshly-killed snake (preferably a cobra) is buried under the plants, for it is believed that the venom potentizes the resin. The rites of *nyasa* and *acamana* are performed while facing north or east. Water is mixed with milk and sprinkled over the seeds. When they sprout, water mixed with clarified butter is used. When the first leaves appear, the plants are sprinkled with salt water. During flowering, the plants are sprinkled with water mixed with alcohol and meat, then with water and honey, and finally with water and alcohol. The rites of *stapana*, *sevana*, *tantubandhana*, and *lavana* are performed before the harvest. The rite of *tantubandhana* should be performed by a purified person on the 14th day of the waning moon (in February-March in India). The plants are tied with red, yellow, black and white threads. The *Aghora mantra* should be recited for a week. On the 5th day of the waxing moon, the cultivator meditates on the *bhang* and imagines her as a deity. When the seeds are fat, the plants are harvested while reciting the *Aghora mantra*.

Cultivators of *bhang* often hire a *poddar* to inspect the plants and cull the males before flowering begins. In many districts of India, farmers stick a knife through the stem near the base of the plant and insert a wedge or nail. Sometimes opium, mercury, sulfur, arsenic, or asafetida is stuffed into the crack to increase the potency of the plant. Certainly, the use of mercury or arsenic is not to be recommended.

Indoor crops can be induced to flower by reducing the photoperiod to under 12 hours for 2 weeks. When the plants have flowered, the males can be culled, and the photoperiod is increased again to resume vegetative growth, but overall development is slightly delayed by this procedure.

Breeders now recognize that the content and quality of hemp fiber is not related to the quantity of psychoactive cannabinoids. Certain varieties are rich in both THC and fiber.

Pruning --- Many cultivators insist that Cannabis grows best if it is left untouched. Others argue that judicious pruning not only alters the appearance of the plant, but also increases the amount of foliage.

The lower limbs or their leaves can be pruned to make more energy available to the upper flowers (This interferes somewhat with metabolic processes by reducing photosynthesis). The large, non-floral foliage also shades the ground, thus conserving water.

Removal of the central bud will produce a multi-stem plant with more foliage. After the plant has produced at least three sets of leaves, carefully cut the central bud (apical meristem). The two remaining axial shoots will develop as stems. These two stems also can be pruned in this manner when they have developed sufficiently. The result is a relatively low, bushy plant. The technique should be used only on young plants; late pruning will interfere with flower development.

Stems and branches also can be trained with a trellis, or tied down close to the ground so as to present a low profile, quite unlike normal Cannabis.

Grafting ---- The Humulus hops plant looks nothing like cannabis, and it can be grafted onto hemp, and it will produce cannabinoids. The technique is not considered to be very practical. **(60)**

I. Bocsa and G. Farkas tested the influence of the slip upon the longevity of root-stock with grafts with hemp varieties with different longevities and between individuals of the same variety/different sex:

"The graft can influence the lifespan of the rootstock. A graft with greater longevity will increase (independently of the sex relationships) the life span of the root-stock. Female slips, which have a longer vegetation period than the males, will increase the life span of the male root-stock." **(61)**

Cloning --- C. Richez-Dumanois, *et al*., studied the *in vitro* propagation of hemp clones, thus:

"Morphological and chemical development decreased at low temperature and were promoted by a regime of 22^{o} C (daily temperature) and 17^{o} C (night) under 24 hour

illumination and 70% relative humidity. Shoot proliferation was obtained with the addition of cytokinin (BAP, 5.10^7 M/liter) and auxin (AIB, 10^7 M/l.). The axillary shoots which developed were used as mother-plants in vitro; they provided numerous cuttings after repeated sub-culturing on the same medium. A long thinning stage was necessary for rooting the microcuttings in the presence of charcoal (2 gr/l.) and AIB (10^5 M). The best method for rooting in vivo shoots involved non-aseptic conditions (3-4 weeks). The further growth of plants at 22^o C/17^o C was comparable to that of corresponding horticultural cuttings and the cannabinoid pattern was similar to that of mother-plants". **(62)**

V. Sustrina cloned hemp as a method of obtaining starting material for selection:

" The best method for the intervarietal grafting of hemp is considered to be by fork grafts of material in the cotyledon phase onto hosts of 7-8 pairs of true leaves... A most promising method is to graft female hemp on males and selfing. The best results were given by the used of female hemp as the host and pollinating the graft with Kavkavskaya hemp."

2.10 ~ Growth Stimulants

The B-vitamins (1 ppm solution) increase the yield of hempseed and its fat content, but somewhat suppresses the growth of leaves, stems, and seed hulls. Potassium permanganate in weak solutions stimulates the development of cannabis in all its phases. Dilute camphor also stimulates plant growth. Vitamin C (1-5 parts in 10,000 water) has the same effect.

The ripening of cannabis flowers can be accelerated by addition of a tablespoon of sugar per gallon of nutrient solution. Do not use this treatment during the initial stages of the flowering cycle, because flowering will be delayed instead.

Auxigro, manufactured by the Auxein Corp. (Lansing, MI; www.auxein.com; US Patent 5,840,656) contains 4-aminobutyric acid, L-glutamic acid, etc.). It increases fertilizer efficiency severalfold and improves plant growth up to 50%. Nutrient accumulation also is increased dramatically.

Triacontanol is a fatty alcohol found in many plants. It increases growth rates and yields up to 25%, and increases the protein content, even during darkness when plants usually are dormant. Triacontanol seems to enhance the growth of plants without increasing their consumption of nitrogen. The simplest way to use triacontanol is to plow under a crop of alfalfa, which contains relatively large amounts of the substance. Triacontanol is extracted from sunflower seeds or alfalfa by chloroform; filter and evaporate the solution to yield crude triacontanol. The dosage is 1 ppm in water.

Carbon Dioxide --- Plants utilize atmospheric carbon dioxide to supply their carbon. The current level of atmospheric CO_2 is about 350 ppm. If the level of CO_2in a closed growing space decreases to below 200 ppm, growth will cease. Levels above 2% can be injurious to both plants and animals. When cannabis is cultivated indoors, the rate of growth and photosynthesis can be enhanced by increasing the concentration of carbon dioxide to about 0.2%. The effects are most influential in the second month of growth.

The rate of growth can be increased about 50% by increasing the level of CO_2 to about 700 ppm. If the level is increased to 1,500 ppm during the vegetative phase, the growth rate will increase up to 80%. The number of females also increases slightly under the influence of CO_2. When extra CO_2 is supplied during the flowering phase, the flowers will mature about 2 weeks sooner, and they will increase in weight about 20%.

To calculate the amount of CO_2 required to enrich a growroom, first select the level of CO_2 you desire (assuming 300 ppm atmospheric CO_2). Multiply the cubic feet of the grow space with the corresponding factor (given below) to determine how many cubic feet of gas are needed to raise the level for each cycle of enrichment. The cycle is repeated as the plants absorb the gas or it is vented outdoors (necessarily when the room temperature rises to 85^{o} F). Commercially available equipment will do this automatically.

For 1,000 ppm, factor (.0007) x cubic feet to determine the requisite volume of gas. 1,100 ppm = (.0008); 1,200 ppm = (.0009); 1,300 ppm = (.0010); 1,400 ppm = (.0011); 1,500 ppm = (.0012).

Gibberellin --- When seeds absorb water, the hormone gibberellin (gibberellic acid-A, GAA) appears in the embryo and activates the metabolism to initiate sprouting. GAA has been widely tested in applications to hemp.

When applied to cannabis at a rate of 100 ppm in water for 2 months, GAA increases the thickness and internodal length of the stock. The terminal nodes are weak, branching is suppressed, and the roots develop poorly. Germination is stimulated by GAA, but leaf growth and the production of chlorophyll and cannabinoids are reduced proportionately. GAA treatment does not hasten the generative development of hemp, but does promote plant growth. The stem diameter increases about 250% over control plants, and the fresh weight of the stem increases 300%. Treated plants have a higher ratio of bark:wood. The number of fibers increases up to 100%.

According to G. Davidyan, the greatest effect is achieved with 0.005-0.01% GAA applied before the buds form.

R. Herich tested the histological reactions of hemp by soaking the seeds in 5 ppm GAA for 24 hours with these results:

"The plants showed the following differences from untreated controls: decrease of stem thickness, less lignification, decreased bark development especially in lower parts of stems, decrease in number of secondary bast fibers, increase in number and size of primary bast fibers, and increased differentiation of parenchymatous pith tissue". **(63)**

C.K. Atal also described the effect of GAA on hemp:

"Gibberellin-treated plants showed a greater number of fibers as compared to controls. The individual fibers were larger in diameter, more lignified, and up to 10 times as long as the fibers from the untreated plants." **(64)**

F. Yanishevskii studied the effect of GAA on the nitrogen metabolism of hemp:

"Stem lengthening took place mainly by cell extension. Net weight even decreased somewhat. Chlorophyll concentration decreased noticeably... Plants treated with GAA contained less N than controls. GAA exerted a considerable influence on the N metabolism of hemp plants: in treated plants the amount of protein N decreased 2-fold, but, in contrast, the soluble forms of N increased markedly. Treatment with GAA had almost no effect on the content of N fractions of cell components (nuclei, plastids). Nucleic acid content decreased mainly owing to decrease in the amount of RNA. Accumulation of soluble forms of N under the influence of GAA would indicate that the introduction of nitrogenous fertilizers (as recommended by Witter and Bucovac) would hardly make up for the unfavorable effect of GAA on the N metabolism of hemp." **(65)**

N. Yakushkina and L. Chuikova also tested the action of GAA and Indole-Acetic Acid (IAA, auxin) on hemp:

"GAA intensified the growth of the plants, the average dry weight per plant, the photosynthesis rate, the sugar content (especially of the stem) and that of total N, and the respiration rate, but decreased the content of chlorophyll in the leaves. The separate application of IAA caused a decrease in the growth and yield of the plants, and a considerable increase in the chlorophyll content, but decreased the photosynthesis rate. The simultaneous application of GAA and IAA was accompanied by the highest increase in yield, but this addition of IAA did not exert any substantial influence on the physiological processes.**" (66)**

GAA also increases the length of the growing season. GAA will inhibit the formation of flowers on Cannabis; it must not be used during the flowering phase of growth. GAA will accelerate the onset of budding by about 7 days.

Treatment of plants with 25 mg GAA/liter results in 80% of the plants being male. Female hemp usually undergoes sex reversal to a male expression, but few of the male plants produce female flowers. Thus, G. Davidyan and S. Kutuzova reported:

"Gibberellin causes the formation of male flowers, containing fertile pollen, on genetically female plants." **(67)**

V. Khryanin treated dioecious hemp with GAA (25 mg/liter) and produced monoecious feminized staminate hemp from the common pistillate form:

"Gibberellin, as a hormone of the plant organism, probably depresses genes which participate in the formation of flowers which have been repressed.

"Thus GAA can be used by breeders to develop monoecious cannabis from dioecious forms. Preliminary tests are necessary to determine the most effective concentration and best timing for each cultivar."

Gibberellin is extracted from cucumber seeds, fresh cantelope seeds, dried corn kernels, and from pencil rod, lupine, and pinto beans. Soak 200 grams of powdered seeds in 110 ml of a mixture of acetone (10 parts), isopropyl alcohol (5 p), ethanol (2 p), and water (5 p). Filter the mush and rinse it with 20 ml acetone and 20 ml isopropyl alcohol. Combine the rinse and the mother liquor, then evaporate the solvent. Dissolve the gum in alkaline water for experimental use.

The effect of GAA is removed by abscisic acid (ABA), which will initiate flowering. Treatment of plants with ABA (10 mg/liter) results in all plants being female or bisexual. The ABA can be overcome by increasing the concentration of GAA. **(68)**

2.11 ~ Harvest

Hemp is ready to harvest after the males have shed their pollen. If hemp is harvested before the males die, then the retting of both male and female plants together is more uniform. The harvest period can extend 2 weeks, but late hemp is more lignified. An early harvest may produce fine, soft fiber, but usually it is weak.

Belgian farmers traditionally harvested their hemp on St. Madelin's Day (July 22). On that occasion they would chant, "Harvest your hemp on St. Madelin's Day. If it's not ready, bale it for another week."

According to the experience gained by Canadian hemp farmers in 1998, the crop should be direct-combined when seed moisture reaches 25-30%, and the wet seed should be aerated within 24 hours after combining.

Yield --- The USDA reported that an acre of hemp usually yields an average of about 7 tons of green stalks. After drying and curing in shocks, the stalks weigh about 5 tons. After retting and drying, the stalks weigh about 3 tons, and they yield about 750 lb of long, rough fiber. The yield of hurds is about 2.5 tons/acre. After hackling, the yield is about 350 lb of single-dressed line fiber, 170 lb of short fiber, and 90 lb of hurds and waste.

Research conducted by Dr. H.M.G. van der Werf showed that fiber hemp yields can be increased by about 30% by growing very late-flowering cultivars at a relatively low density (<300 plants /m^2). The crop self-thins due to inter-plant competition, and it is harvested late in September.

According to Dr. Ivan Bocsa, the stalk yield of hemp for Class I (rich) soil is <2.7 to >3.8 short tons/acre. The lower quality Class II and III soils yield <1.8 to >2.9 short tons/acre.

The Hungarian dioecious variety Kompolti, which currently has the highest fiber content in the world, produces yields of about 9 tons stems/hectare. The Polish varieties Beniko and Bialobrzerzie produce about 100 kg seed/ha, plus 9-10 tons of dry stalks/ha. The varieties mature in late September. Ukranian seed such as Zolotonosha and Glukiv USO have been tested in Manitoba and Ontario, Canada. They have vegetative periods of 110-150 days and yield 0.25-0.5 tons seed/acre and 3.25-5 tons of stalk/acre. In Australia, the yields of stalks average from 8-10 tons/ha; in the Ukraine, 8-10 tons/ha; in the Netherlands, 10-14 tons/ha; in the UK, 5-7 tons/ha. The low average is about 6 tons of stalk/ha, yielding a low of 22% bast fiber. The high yield is about 10 tons of stalk/ha, with a high content of 30% bast fiber; thus, yields range from 1.3-3.0 tons of fiber/ha.

Thomas Jefferson simply noted the following regarding the yield of hemp:

"Tolerable ground yields 500 lb to the acre. You may generally count on 100 lb for every foot the hemp is over 4 ft high."

S.S. Boyce (*Hemp*, 1900) stated likewise:

"Hemp yields 150 pounds of fiber per acre for each foot in height, hence the advantage of a tall plant."

Equipment --- The World War Two film *Hemp for Victory!* showed farmers the best equipment then available to harvest the crop:

"Hemp grows so luxuriently in Kentucky that harvesting is sometimes difficult, which may account for the popularity of the self-rake with its lateral stroke. A modified rice binder has used to some extent. This machine works well on average hemp... An improved hemp harvester... spreads the hemp in a continuous swath... In Kentucky, hand cutting is used to open fields for the machine. [The] hemp is shucked as soon as safe, after cutting, to be spread for retting later in the fall.

"In Wisconsin, hemp is harvested in September. Here the harvester with automatic spreader is standard equipment. Note how smoothly the rotating apron lays the swaths preparatory to retting. Here it is a common and essential practice to leave headlands around hemp fields. These strips may be planted with other crops, preferably small grain. Thus the harvester has room to make its first round without preparatory hand cutting... When the cutter bar is much shorter than the hemp is tall, overlapping occurs. Not so good for retting. The standard cut is 8 to 9 feet...

"When conditions are favorable, the pickup binder is commonly used. The swaths should lie smooth and even with the stalks parallel. The picker won't work well in tangled hemp. After binding, hemp is shucked as soon as possible to stop further retting.

"A helper with a hooked pole may be required to pull out problematic "volunteer" stalks, which are difficult to cut. Volunteer hemp grows from seeds scattered by the previous crop. Such seed sprouts earlier than sown hempseed and grows taller than the rest of the crop."

When hemp grows to a height of 15 ft or more, a self-rake combined reaper and mower works well. Modified rice binders also have been used to bundle hemp. A sweep-rake reaper can cut 5 acres or more in a day, and a mowing machine can harvest 7 to 10 acres. The British Hemcore project used a modified rape swather and round balers. French farmers have reported using modified silage maize harvesters. In the French method of harvesting for seed, a combine harvester is used to cut the upper parts of plants, but the cutter bar must be raised to its maximum heigh (about 180 cm). At this height, some fiber yield is lost because more than the seed-bearing portion of the stem is removed. Good timing is of vital importance, but efficiency is low because the seed does not mature uniformly. If the hemp is dual-purpose crop, the fiber can be contaminated with seed and foliage, some stems will be lost under the wheels, and field-drying may not be feasible due to the lateness of the season. After harvesting the seed, the remaining stem can be cut with a finger mower. A narrow draper-style windrower cannot handle tall hemp, but a wide draper or auger windrow may be satisfactory.

The Dutch Hemp Research Programme (DHRP, 1990-1994) cut its hemp with a mower conditioner. The crop was field-dried at least 4 days to reduce the moisture content below 15% so as to avoid the decay of fiber by bacteria during the storage of dry hemp. Because of erratic weather conditions, field drying is not a reliable practice in Europe. The seed was harvested by cutting off the stem tops and threshing them with a combine. The stalks were round-baled. Minor problems caused by pickup blockages can be avoided by reducing the windrow volume and ground speed.

The DHRP also developed a new method of "direct harvesting" using field choppers equipped with a row-independent header. The operation loosens about 90% of the core and bark, but the sharpness of the chopper knives and the throughput of the stalks causes problems with wrapping and blocking. Field chopping is advantageous in that the stalks are not dried in the field; the pieces are immediately stored in a silo, thus avoiding the vagaries of weather. The maturation and harvest periods can be extended, and the labor is reduced considerably.

In their review of the hemp harvest and storage techniques developed by the DHRP, Huisman and de Maeyer concluded:

"With decortication, the bark could not be cleaned well enough and still contained more than 40% of the core. Bark and loose core should be easily separable by sieving since the size of the bark [0.5-2.5 cm] and of the loose pieces [1-8 cm] greatly differ... It was clear that the quantity of fixed core mainly depended on stem diameter; the smaller the diameter, the higher the quantity of fixed core...

"With field chopping, the bark was not cut as short as the hurds; this made it possible to separate bark and core by sieving or flotation. Sieving of chopped hemp resulted in a "contamination rate" of both bark and core of about 25%... The size difference between the chopped bark and core was not big enough to separate them by sieving. With flotation, very clean bast could be collected, although some bark floated because it stuck to a piece of core, resulting in its collection with the core... Because the bark sinks in water and the core floats, flotation is an easy and effective separation method. This operation perfectly fits into a harvesting system with chopping and [wet anaerobic] ensiling..."

Problems with fiber tangling can be avoided if the stems are cut into lengths of 5-10 mm during the harvest. A modified forage harvester can be used; the cut straw is fed into a hopper bin. A stationary 5-blade chaff cutter has been used, with a uniform cutting length being achieved by feeding the stems end-on into the cutter and minimizing the gap between the blade and cutting face. Over-long pieces can be removed by a sieving table, then fed back into the system.

The Dutch company HempFlax Akkerbouw has developed a cutter mower that chops hemp plants into three half-meter pieces. The machine cuts about 7.5 acres/hour. The machine mows the plants down and picks up the stems. Metal brushes remove the leaf material and push the stalks lengthwise into the chopper. The cut stems are dropped in a row behind the machine to be picked up by a standard bailer. The company also has developed a turning machine that turns over the stalks in the field without causing damage to the fiber. John Deere manufactures the improved HempFlax Kemper cutter.

Experimental plots grown by the Canadian Industrial Hemp Council were harvested with a sickle type of cutter, but the results were unsatisfactory. A disc-bine also was used and worked very well. Robert Guilford commented:

"The added bonus of this machine was that it crimped the stem, allowing for faster retting. The part that I left for the combine ended up being a mistake. Putting all that stalk through to get the top foot was not one of my better ideas. It took me 6 hours to unplug the combine... In 1996 we waited for a frost and then brought in a combine with a straight cut attachment. It cut the plant off at the 4 foot level and so it only had to deal with the top 3 feet or so. We then came in with the disc-bine to cut the remainder of the stalk off for [round] baling... If the hemp can find a place to wrap when it's a bit damp it will."

According to the moisture chart developed in 1999 by the Canadian Grain Commission, hemp farmers should direct combine hemp when the seed moisture is between 25 and 30%. The Canadian farming magazine *Western Producer* (www.producer.com, 9-9-99) offers the following tips for combining hemp safely:

"Raise the cutter bar as high as possible to minimize the amount of material the combine has to process. Lower the cylinder speed to about 350 rpm and have the concave about half open. Use plenty of air to remove leaves, chaff and small or empty seeds.Remove straw chopper and blades.Cover exposed shafts with shields.Go slow. Expect to combine 1.5 to 5 acres per hour. Get off the combine and inspect for fiber wrapping every 45 minutes."

Methods --- The process of harvesting large fields of hemp (over 100 acres) in Hungary includes a preliminary chemical defoliation to remove the unnecessary burden and volume of leaves (up to 20% of the plant weight). Foliage increases the cost of handling, transportation, and storage, and it reduces the capacity of retting basins and discolors the stalks. Manual defoliation is not feasible, and mechanical methods have not been successful. The defoliants Purivel (Metoxuron), Basta (ammonium glufosinate) and Round-up (20% glyposate) are applied by airplanes or orchard spray guns when the 10-15% of the male plants have flowered (within one week of technical maturation). These substances are toxic and pose grave environmental threats.

G. Venturi reported on the use of defoliant-dessicants for hemp harvesting in 1970. Reglone (4 kg/ha in 15 hecaliters of water/ha) was the "most satisfactory" of 18 products tested; it was applied at the usual time of harvesting (when about 75% of the males are flowering) while postponing the mowing up to 7 days. While defoliant-dessicants were useful for fiber production, it was not good when the hemp was to be used for paper production.

The Humorous Hemp Primer also advised farmers on the subject of harvesting:

"Using a bailing mower will save much work, time and effort, but it can only be used with lower-grown crops. That is why German inventors provided us with a hemp mower-bailer which neatly cuts and ties and places hemp to the side.

"So the crops can dry out quickly, carefully stack them in round manner using 16 bundles standing upright. When nicely placed, strong winds can blow right through them for rapid drying.

"Fiber stalks deteriorate quickly if left out to dry too long. They cannot tolerate fall rains. The fibers shrink and gum up and the birds pick at them... Hemp in the shed or stack now browns in the sweating process. This stage of its life lasts about 6 weeks and is healthy for the plants since the seeds grow into full ripeness and readiness

"This period of storage also allows the hemp stalks to ripen, mellow, and cure, to "gather nature" and "quality". This nature and quality is further developed by the subsequent manipulations to which the fiber is subjected, and eventually produces the desired high, silky character."

S.S. Boyce offered this advice for harvesting hemp:

"In whatever way the hemp is harvested, it is at once bound up in small sheaves when pulled, and stood up to dry, and then shocked. The seed is beaten out, the tops and roots cut off, to even it in length, by a sharp cutter. Or after the roots are cut off the hemp is stood up, bundle by bundle, and the taller stalks pulled out."

John Bordley gave this warning to farmers in his pamphlet on *Hemp* (1799):

"In America, Hemp and Flax are commonly dry before they are spread to be dew-rotted. If spread before the last of September, they become sunburnt, red, harsh, and dead."

Mechanical harvesting may not be possible or practical in very small fields of seed hemp or in underdeveloped countries. Therefore, some specific techniques are to be recommended. An experienced worker using a hemp scythe can cut about half an acre in a day.

In the opinion of the Anonymous Farmer, hemp should be harvested as follows:

"This is the best and easiest done when the ground appears to be tolerably dry. When you begin to gather the HEMP, it will be expedient that each person employed clear before him as many feet of ground as the HEMP is high, in order that, after pulling it up by the roots, and beating off the earth that sticks to them, by striking the roots against his foot, he may conveniently spread it on the ground from whence he has pulled it, where it must lie until it is quite dry; it is then to be tied up in bundles, and put under some cover, or carefully stacked on the ground, in which case it must be well thatched with straw to prevent any wet from getting to it. Under this shelter it remains until about the middle of November, when it is spread out to rot; it is spread out in rows, taking care that it is spread so thin that it may get equally wet, and dry nearly alike... from this time it generally lies till towards the beginning of February... The proper time for taking it up may be easily known by cracking a few of the stalks, or breaking a handful in the brake, and if the bark is found to separate readily from the stems, the HEMP ought immediately to be taken up, which must however be done in clear weather, that the HEMP, when lifted, may be as dry as possible... When it is not convenient to brake it directly, it should be put under cover, so as to be entirely safe from the weather."

Lionel Slator described this meticulous Dutch method of pulling hemp in his *Instructions...* (1724):

"In Holland, they pull the long fimble-hemp separately and apart from the short; especially, such as they perceive to have shed its Leaves and Blossoms, because the short Fimble is longer Time at rating [retting] than the long Fimble is: They are so careful not to break or bruise the Carl-hemp, as they pull the other, that when they pull their Fimble, they are forced to take off their Coats and Shoes, and tuck the Skirts of their Vests within their Breeches, and also have the Sleeves of their Vests made so tight to their Arms, as none of their Cloaths might break or bruise the Carl-hemp...

"The pulling of the long Fimble hemp apart from the short, is not only necessary with regard to the Watering [retting], but also of absolute Necessity in the working of them; for should the long Fimble-hemp be broke, and hackled promiscuously with the short, it would occasion vast waste; for the Artist always holds the Roots in his Hands, as evenly as he can. When he breaks or hackles, he must work the whole Hemp equally down to the Roots; and if they be of a very unequal Length, the Tops of the long Fimble will be over wrought, and rendered useless, if any of them should happen to remain". **(69)**

If the hemp is left laying in the field after mowing, it must be turned over after two or three days. This is done by thrusting a fork under the stalks near the tops and throwing them over on their butts. The stalks are left to dry for another few days, and then the field hand ties them in bundles about 1 foot in diameter with a length of old rope, pre-cut to the right length and looped at one end. One man can bundle from 1-1/2 to 2 acres in a workday.

The stalks should be shocked within a few days after harvest to avoid scalding. Sunburned fiber is unevenly colored and usually weaker. The stalks should be relatively free of leaves so the tops of the shocks are smaller and less rain can enter. Hemp stalks are bound in bundles about 10 inches in diameter, using small hemp stalks to tie them. The stack must be built to shed water, being higher in the center with sloping sides, and capped with an upright bundle.

The stacks of sheaves must dry out for one week (until the moisture content is less than 16%) before they can be handled by a bale-press. Alternatively, if the local weather permits, the stalks can be left in swaths for a month or more while they are repeatedly wetted by dew and dry out. Such "pre-retted" stalks can be water-retted more quickly, or they can be mechanically processed immediately without retting. Baled hemp should be removed from the field as soon as possible. If they are wetted by rain, the bales must be opened and the sheaves stacked to dry out before pressing them again.

The low-quality stalks that remain are gathered and burned (unless prohibited by law) in order to discourage hemp borers and recycle the nutrient ashes. The stubble also should be burned, because it does not decompose easily. Failure to do so will impede subsequent tillage and sowing. The only alternative is to chop the stems and stubble to 0.5 inch or smaller pieces with a chaff cutter. Plow the field and add nitrogen fertilizer to accelerate the process of decomposition.

The complete plant has the following composition: C (38.94%), H (6.06%), N (1.74%), O (48.72%), ashes (4.54%). The stalks contain: C (56.80%), H (6.48%), N (0.43%), O (34.52%), ashes (1.77%). The leaves contain: C (40.50%), H (5.98%), N (1.82%), O (29.7%), ashes (22%). The ashes of the hemp plant contain: KOH (7.48%), $NaCO_3$ (0.72%), CaO (42.05%), MgO (4.88%), Al_2O_3 (0.37%), SiO_2 (6.75%), H_3PO_4 (3.22%),

H_2SO_4 (1.10%),Cl (1.53%), CO_2 (31.90%).The ashes of the seeds contain: KOH (20.81%), $NaCO_3$ (0.64%), CaO (25.57%), MgO (0.96%), FeO_2 (0.74%), H_3PO_4 (35.52%), $CaSO_4$ (0.18%), NaCl (0.09%), H_2SiO_3 (13.48%), C (6.19%).

2.12 ~ Hempseed

A frost not exceeding 6° below freezing will not injure hemp except to stop further seed production and make the seeds shatter more easily. If possible, the seeds should be harvested on a cloudy day before noon when moisture helps prevent the loss of seeds by shattering. If a combine harvester is used, the weather should be sunny and dry. If the plants are manually harvested, they are cut down with corn knives, and shocked up around a few plants that have been left standing. After two weeks of drying, an entire shock is thrown onto a tarpaulin and thrashed with long sticks. The shock is turned over and beaten again. Two or three pecks of seeds can be collected from a shock of hemp. Because the seeds fall so easily from the dry plants, it is impossible to remove them without great loss and difficulty. The plants are so tall and branched that they cannot be fed easily into a thrashing machine.

If the crop is cultivated for both seed and fiber, the plants are harvested in two stages: (1) the seed-bearing tops of the plants are cut off and threshed; (2) the remaining stalks are harvested. An axial-flow combine harvester with an elevated cutting table can be used, but the rollers must be modified to avoid damage to the machine, and it must be operated at high speed so that the cut pieces will fall into the chopper.

Hempseed is cleaned first through a clod sieve with quarter-inch round slits, then through a seed sieve with 0.08 inch elongated slots, then through a fanning mill. Properly cleaned hempseed weighs 44 lb/bushel. A low yield of hempseed is about 300 kg/acre; a high yield is about 500 kg/acre, or 0.7-1.2 tons/ha. Some fiber yield is lost in the harvesting of seed hemp crops. The average yield is about 25 bu/acre, or about 700 kg/ha. The collection and cleaning of hempseed can be done only in dry weather.

Hempseed should be aerated within 24 hours after combining. Freshly threshed hempseed contains up to 20% moisture, and must be dried until the moisture content drops to 12%, preferably between 9 and 10%. Artificial drying should not exceed 40° C (105° F). One year of aging at 7-15° C with 65-75% humidity increases their viability about 15%. Hempseed should be kept cool and dry, as it spoils quickly under warm and damp conditions. Another method of preserving hempseed is to dry at 80° C for 15 minutes, or at 50° C for 4 hours. The temperature must be even: beginning the drying at a lower temperature and ending at a higher temperature will reduce the power of germination. The loss of germination potential can be prevented for about two years by cold storage (0-5° C/32-40° F) at low humidity. The germination rate can be maintained at 90% for up to five years by storage at -10° C (14° F).

Francesco Crescini studied the environmental and genetic factors that cause variations in seed germination, and developed a simple method for increasing their viability:

"Seed kept in in paper bags after harvest for 8-9 months, at 7-15° C and 65-75% air humidity, have a 10-15% greater viability than those after-ripened only 2-3 months. The

physiological final ripening of the seeds is accomplished on the plant by drying the female stems after harvest at a shady place for 7-10 days... Lines of different germinating power may result, even from pure lines, under conditions of self-fertilization. Cross-pollination eliminates lethal factors which are responsible for low germinating power. The percentage of viability and the readiness to germinate are independent genetical characteristics. The longevity of hemp seeds does not seem to be hereditary and is not correlated with either their viability or their readiness to germinate." **(70)**

The Humorous Hemp Primer has this to say about the storage of hempseed:

"Never place the seeds in sacks, since they would get terribly hot and sweat themselves to death. Rather, use the proven method of spreading seeds gently on the floor, up to 10 inches deep. Use your hands and a shovel to gently turn and keep the seed alive. Early on it must be turned every other day. To avoid damage, wear felt shoes or cover your shoes with sacks. Hemp seed is only ready for storage when its humidity has sunk to 8%."

In fact, hempseed can be stored in sacks after it has been dried sufficiently, but it cannot be kept in a dry storeroom because the seed will lose its viability or become infested with bacteria. Hempseed should be sacked in 2-bushel bags; these are piled in groups of two, side by side, then two across.

Edward Quincey warned posterity to exercise caution in handling hempseed:

"The Farmer must be very careful in saving his seed, which by no means must lye too thick upon his floor, lest it heat and thereby be spoiled; to prevent which, let him stir and turn it frequently till it be dryed."

Lionel Slator gave this description of the traditional Dutch method of handling hempseed:

"When the Seed is thus thrash'd out of their Hemp, they convey it to a well-boarded Floor, where it is laid... about two or three inches thick, and they turn it once a Day regularly, during the first three Weeks, not suffering the Man who turns it, to have either Shoes or Pumps on, lest he should break or bruise the Seed by treading on it. About three weeks afterwards, they clean their Seed again, but not entirely from the Chaff or Dust... They leave that to remain with the Seed, until such time as the Seed is compleatly dry; because it is their Opinion, that this Dust and Chaff prevents the heating of the Seed as it lies drying... They continue the Seed still on the boarded Floor, and observe to turn it twice a Week, till the Season comes for sowing it."

The Anonymous Farmer from Annapolis advised against the Dutch method of collecting seed:

"Though this is the method... generally used for raising seed, yet it is by no means to be approved of; separating the seed plants from what you pull up occasions a great deal of trouble, and takes above double the time to gather and secure the HEMP from off the same ground... A far better method is to raise the seed apart by itselfe... An acre of ground, managed in this manner, will produce from 20 to 25 or 30 bushels of seed."

Edward Antil recommended this method of harvesting seed hemp:

"As the first seeds are the fullest and best, they are worthy of some pains to save them: and the best way to do that is, to bend down the plants all along... and shake them over a cloth spread on the ground to receive the seed; if one side of the plant be rooted out of the ground by forcing it down to shake out the seed, there will be no damage, for the seed that remains will ripen notwithstanding; and the plant must thus be shaken every two or three days, till all the seed be ripe and thus saved; and this is much better than pulling up the plants by the roots, and shaking them on a barn floor... for by this method, which is the common practice, one third of the seed at least never comes to maturity."

2.13 ~ Apologia

The anonymous Farmer from Annapolis ended his *Essay on the Culture and Management of Hemp* (1776) with this apology:

"Surely it is unnecessary to enlarge further on this head, and indeed the author fears that he may be thought too prolix, especially by those already acquainted with the subject, but when it is considered that these instructions are intended for the information of thousands, who have perhaps never seen the plant, he apprehends that the directions could not be too minute or particular."

Lionel Slator offered the same reason in his *Instructions* (1725):

"I shall conclude this Section with this general Apology in my own behalf, for being so large in my Observations and Remarks through this System of flaxen and hempen Agriculture, That I conceive it to be so much my Duty, fully to inform all Persons engaged or to be engaged in this important Matter, that I submit rather to be censured as prolix than deficient."

S.S. Boyce gave a similar accounting for himself in his treatise on *Hemp* (1900):

"There should be no necessity for an apology or an excuse for preparing a work upon hemp culture at this time. The hemp plant is the most widely diversified and, commercially and industrially, the most important plant in cultivation in Europe. It was among the first introduced into America, and one of the most extensive in cultivation among the colonists; and there is no good reason existing why it should not, but every reason why it should, today be among the first as a basis of another great and grand national industry, employing hundreds of millions of capital and hundreds of thousands of work-people."

2.14 ~ References

Table 2.5 ~ Hemp Farming

Operations: Plow ~ Disk ~ Harrow ~ Drill ~ Roll ~ Reap ~ Bundle ~ Thresh/Clean Seed ~ Spread ~ Pickup ~ Decortication ~ Bale ~ Transport ~ Storage; (Section 2.1)

Soil: Fall: plow (8"); apply amendments ~ Spring: disk harrow & roller; (Sect. 2.2) ~ Water furrows to ditch every 30-40 ft as needed ~ Microbial formulas (Bacillus subtilis, &c)

NPK: Manure, compost, cottonseed meal, bonemeal (200 lb/ac) &c; (Sect. 2.8) ~ NPK: N 100-150 kg/ha (<400 ppm); P 80-100 kg/ha; K 100-180 kg/ha ~ Gibberellin & c (Sect. 2.10)

Seed: Grain drill or alfalfa seeder (modified); (Sect. 2.5); Fiber Crop: 7.5 or 12.5 cm rows, 55-100 kg/ha; maximum depth 1.5"; Seed Crop: 10-15 kg/acre ~ 2 ft rows ~ 2-3 seeds/ft; thin to 1 plant/20" ~ Fiber & Seed

Crop: 12-20 kg/ha < 16" rows ~ 7 seeds/ft . Drill in with superphosphate/confettatura ~ Electroculture (Chap. 5)

Water: 20-30" +; 70% relative humidity; irrigate; 80-130 gal/kg fiber; (Sect. 2.3)

Temperature: Soil: 35^{o} optimal @ sowing; air: 19-25^{o} C optimal; (Sect. 2.4)

Intercrops: Mustard, broccoli, brussel sprouts, lupine, nettles, hops, turnips; (Sect. 2.6)

Crop Rotations: Corn, potatoes, onion, peas, beans, wheat, clover, barley, oats, grass; (Sect. 2.6)

Calendar: 100-115+ days, <frost - frost>, April 1+

Equipment: Tractor ~ plow ~ disk ~ harrow ~ drill ~ roller ~ J. Deere Kemper harvester (or: self-rake reaper-mower, sweep-rake reaper, modified rape swather, mower conditioner) ~ baler (or: modified rice binder) ~ clod sieve (seed-cleaning: 1/4" round slits) ~ flatbed truck/trailer ~ forklift ~ pumps ~ tools ~ fuel ~ barn ~ scales ~ Hill/Agra Decorticator

Expenses: ~ $200/acre (Sect. 2.1)

Yield: Seed: ~ 0.4 ton/acre (300 gal. oil) > 1.2 tons/ha; (Sect. 1.7, 2.11, 4.7) ; Fiber: average ~ 2 tons/ha; maximum: ~ 12 tons/ha @ 115 days (Kompolti).
