Station Circular of Information No. 153 June 1936

SOIL, NUTRIENT AND IRRIGATION REQUIREMENTS OF FIBER FLAX

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Suitable soil maintained in a good state of fertility and tilth is of primary importance in the successful production of fiber flax in the north Pacific coast region. Progress has been made in recent years toward successful mechanization of harvesting operations, and modern scientific and mechanical skill should help to firmly establish processing and milling operations to provide local markets and manufacturing plants for flax produced. Flax growing promises to provide an additional cash crop to the farmer, for which there should be a protected market in this country. According to Thomas Bowman, Chief Counsel for the U. S. Government at Belfast, the linen goods imported into this country annually have a retail value of approximately $50,000,000. The linen textile industry of Belfast alone is reported to employ 85,000 workers. The possibilities in flax and linen under western Oregon climate cause much interest in the industry. This article is prepared in the hope of directing flax soil selection and management methods along suitable lines.

The general soil conditions suitable for fiber flax include good drainage, a good supply of nitrogen and organic matter, and slightly heavy textured soil such as silt loam, having good tilth, and usable water capacity and fertility. Early plantings on clean, well prepared clover sod land seeded around March 15 to April 10 have been most successful. Supplemental irrigation has been very helpful, especially when there was dry weather in June. Early planting permits taking advantage of the spring moisture, and moist atmospheric conditions in early season, and brings on the "grand period of growth" during the longest days of the year, which was proved by Redington and Priestley (1925) to be important in fiber flax production.

Flax Soils

The recently completed soil survey of the Willamette Valley and a study of the flax crops in recent years shows there is an abundance of land suitable for fiber flax production in this region. Soils on the old valley filling or the main valley floor well suited for fiber flax production include those of Willamette and Hillsboro series, and also the soils of the Amity series where needed drainage has been provided. The Willamette series includes 351,680 acres and the Amity series 277,568 acres, so that there is over half a million acres in the main valley floor capable of producing flax. Some of this land is now devoted to permanent crops. These soils are suitable for flax growing about once in four years in a crop rotation that will include grain, clover and a cultivated crop. The clover sod will supply nitrogen and the cultivated crop helps to eliminate weeds. It should not be difficult to find 50,000 acres a year that could be devoted to fiber flax if market and economic conditions come to warrant it. The soils from flax contract fields were tested and found to be moderately acid with 1 to $2\frac{1}{2}$ tons of lime requirement and the available phosphate was moderate in amount, ranging from 25 (low) to 125 (good) pounds per acre to plow depth.

The recent stream bottom soils include some good flax land, principally the soils of the second bottom of Chehalis series, with a total area of 215,715 acres. Flax has also been successfully grown on the soils of Sauvie series and on shallow muck. These latter two soils series are suitable for fiber flax only when needed drainage has been provided. There are approximately 24,000 acres of Sauvie, mainly in Multnomah County, and 2,000 acres of muck and shallow peat, making about a quarter of a million acres of bottom land, of which perhaps 25,000 acres should be available for flax production annually in a four-year rotation. It should not be difficult, therefore, to grow as much as 50,000 acres of flax on the main valley floor, 25,000 acres on suitable bottom land, if market and economic conditions should come to warrant it. Robinson,(1932) reported most of the fiber flax grown in Oregon was planted in three soil series with the following production: Chehalis - 3,514 lbs. per acre; Willamette - 3,099 lbs. per acre; Amity - 2,633 lbs. per acre.

Fertilizer or Nutrient Requirements of Fiber Flax

The Soils Department of the Oregon Agricultural Experiment Station has conducted field and plant house studies of the nutrient requirements of fiber flax for a period of nine years. Review of the literature and early results obtained have been reported previously by Powers (1928). Flax was grown in water cultures, soil plats, and field fertilizer trials with a view to obtaining information as to nutritive requirements of this plant for maximum fiber production. Potassium nitrate was found to be a promising potash carrier and potash was found important in the early growth period. Potash seemed to increase the yield and also the length and strength of fibers.

Earlier experiments have given indication of the value of potassium sulfate for inducing increased fiber yields, particularly when used in conjunction with nitrate. The effect of nitrate on vegetative growth has been marked in some experiments. Workers have shown instances where nitrate increased fiber yield less than it did straw yield, while potassium seemed to affect fiber production more. There is also an indication that superphosphate is effective in increasing the seed yield, while potassium sulfate increases the ratio of fiber to that of seed.

Further Fertilizer Trials

A fertilizer trial was initiated on Willamette silty clay loam near Monmouth, Oregon, beginning 1927, and continued four seasons. June 18, 1930, the flax of certain fertilized plats had received potassium and nitrate or complete fertilizers, and was approximately 4 feet high. Yield data apparently was not secured (during absence of the writer for Second International Soil Congress). This trial has been moved from field to field, and has generally been on clover sod land and always on Willamette silt loam soil, though treatments have been applied each season at a new location.

The results, Table 1, indicate that potassium is of importance in making for length and strength of fiber; and that nitrate supply is essential to secure full returns from the potassium. Field observations indicate that a small amount of phosphate included in the treatment may help rooting and avoid lodging. Where phosphate has been included in the treatment it has hastened blooming and encouraged branching, which is objectionable to fiber flax, but perhaps desirable for seed flax.

A plant house fertilizer trial has been maintained for four spring seasons, using fourteen 4-gallon stoneware jars filled with Willamette silt loam soil from the college farm. The jars were refilled in 1929 and the treatment simplified so that four jars of each treatment were provided instead of two, as in previous years. The yield is presented in Tables 2 and 3.

Potassium nitrate has frequently given a maximum yield and height in these trials. The retted fiber was judged as to quality by Superintendent Fitzgerald, of the Oregon Linen Mills, who has had 25 years' experience in the flax industry, and who placed the retted, scutched fiber from the plat receiving potassium nitrate as first in relative quality, without knowing the treatment under which the various samples for judging had been produced.

Microscopic and X-Ray Studies

Microscopic examination of many stained cross sections of fertilized and unfertilized flax stems and fibers show that potassium increases the plumpness and causes wedging or crowding. X-ray photographs, secured through cooperation of Professor Dore, of the University of California, show no difference in individual cellulose units resulted from fertilization.

Fertilizer for Fiber Flax on Muck Soils

Fiber flax has been observed to make excellent vegetative growth on muck soil yet the yield of fiber was disappointing. A trial was conducted with peat soils from Lake Labish, Oregon during three seasons, to determine the value of potassium and other fertilizers for increasing the fiber flax yield on organic soils. The results of the trials for the two seasons are reported in Tables 4 and 5.

In 1928 manure produced the maximum yield, although a combination of potassium and nitrogen yielded nearly as high. In 1929 a complete fertilizer produced the maximum yield, but it was practically equalled by the use of manure and potassium chloride. Trials with numerous peat areas show that this soil is low in water soluble potassium, and that additions of potassium increase the yields of various crops commonly grown on muck soils in Oregon. A little well rotted manure seems to inoculate the peat and aids its decomposition and formation of nitrates. It also increases the water soluble potash, according to laboratory studies reported elsewhere by Powers (1930). Lime on acid peat corrects acidity and aids nitrification. The liberation of some potassium by base exchange may also occur.

While good peat soils will perhaps be employed for more intensive crops than fiber flax, yet there are areas of shallow peat and muck soils, which by fertilization with potassium salts and other indicated treatments following drainage, produce flax fiber of excellent length.

Irrigation

Supplemental irrigation seems to aid activity of beneficial micro-organisms of the soil and promote the liberation of nutrients for plants. One five-inch irrigation has increased the length of fiber flax 20 cm. and has given a 4-year average increase in yield of .91 ton an acre; or an average gain in net profit of $12.35 (Table 7). Irrigation may be helpful in retarding ripening so that pulling may be completed before the plants are dead ripe. This should aid in securing a high quality of fiber. Tall flax is not only more valuable but is more readily harvested, either by hand or with machinery. With irrigation and fertilizer the total yield has been increased as much as 2.11 tons an acre (Table 6).

YIELD, HEIGHT, AND QUALITY OF FIBER FLAX IN FERTILIZER TRIALS ON WILLAMETTE SILT LOAM, MONMOUTH, OREGON, 1927, 1928, and 1929 - Table 1.

Treatment				Yield per Acre						
Nature	Amount per Acre			1927			1928		1929	
	1927 lbs.	1928 lbs.	1929 lbs.	Per A. lbs.	Height cm.*	Qual. of fiber	Per A. lbs.	Height cm.	Per A. lbs.	Height cm.
None	-	-		4200	55	11	7520	63.0	-	-
Nitrate of Soda	100	100		4640	61	3	8160	68.0	-	-
Superphosphate (acid phosphate	200	200		3920	55	5	-	-	-	-
Potassium Sulfate	100	100	200	4000	66	4	8000	63.0	9280	58
Potassium Sulfate	-	-	400	-	-	-	-	-	9120	57
Nitrate and Potash	100	100		4800	69	1	8220	69.0	-	-
None	-	-		4600	65	7	7360	65.5	7840	49
Potash and Superphosphate	100	100		4480	58	8	8000	69.0	-	-
Potassium Sulfate Ammonium Sulfate	-	-	100 & 200	-	-	-	-	-	8320	52
6-7-8[a] 1927 (10-5-10) 1928	100	250		4640	55	6	8800	70.0	-	-
6-7-8 1927 (10-5-10) 1928, (10-10-10) 1929	200	500	500	3520	55	10	8960	68.0	10240	64
6-7-8	300	-		3520	61	2	-	-	-	-
None	-	-		3360	54	9	7840	63.0	8320	52

Tensile strength (Average of 10 tests, 6 strands each).
* 30 centimeters is approximately one foot.
a Nitrogen, phosphorus and potassium, respectively.

Table 2

Fertilizer Experiment with Fiber Flax - 1927-30

Willamette Silt Loam Soil in 4 gal. Stoneware Jars

Pot No.	Treatments		Yields					
			1927				1928	
	Nature	Rate per acre	Ave. Height	Ave. Weight	Tensile Strength	Compara-ative Quality	Ave. Height	Ave. Weight
			cm.	gms.	oz.		cm.	gm.
1 & 2	Check	-	70	29.5	36	6th	95	31.1
3 & 4	$NaNO_3$	200#	78	39.1	38	5th	110	60.8
5 & 6	$CaH_4(PO_4)_2$	200#	67	19.5	35	4th	102	40.3
7 & 8	K_2SO_4	200#	65	20.8	52	3rd	95	35.1
9 & 10	KNO_3	200#	80	41.5	45	1st	110	58.3
11 & 12	K_2SO_4 $CaH_4(PO_4)_2$	100#) 100#)	75	22.8	56	2nd	98	37.4
13 & 14	KNO_3 $CaH_4(PO_4)_2$	100#) 100#)	80	36.8	57	7th	110	48.0

Table 3

Fertilizer Experiment with Fiber Flax

Willamette Silt Loam Soil - 1929

Pot Nos.	Treatments		Yields	
	Nature	Rate per Acre	Ave. Height in Cms.	Ave. Dry Wt. Gms.
		lbs.		
1 - 4	(KCl ($NaNO_3$ ($CaH_4(PO_4)_2$	50) 50) 100)	74.8	26.6
5 - 8	Check	--	71.0	24.7
9 - 12	(KCl ($NaNO_3$	100) 100)	73.5	32.5
13 - 16	KCl	200	84.8	19.3

Table 4

Flax Yields - Lake Labish Peat - 1928

Plants Grown in Pots

Treatments		Yields	
Nature	Rate per Acre	Ave. Height	Dry Weight
	Tons	cms.	gms.
Check	-	114.3	48.6
Lime	2	115.5	43.9
Manure	12	118.0	67.0
Potash	.1	116.8	48.5
K and N	.1	121.9	56.8
Lime and Potash	2. .1	115.5	55.1
Lime and Manure	2 12	114.3	57.1
Lime, Potash and Manure	2 .1 12	115.5	54.6
Excess water	-	86.3	10.1
Complete (4-5-5)	.25	109.2	49.2

Table 5

Flax Yields - Lake Labish Peat for 1929

Plants Grown in Pots Containing 14# Air Dried Soil

Treatment		Yields	
Nature	Lbs. per Acre	Ave. Height	Dry Weight
	lbs.	cms.	gms.
Potassium Chloride	200	61.3	36.8
Sodium Nitrate and Potassium Chloride	100) 100)	73.6	42.1
6-7-8	200	68.3	44.2
Manure and Potassium Chloride	10T) 100)	67.6	43.6
Lime + Potassium Chloride	2T) 100)	65.0	38.0
Potash-compound (contains K, Ca, Mg, & SO_4)	400	64.6	39.6
Check	-	66.3	33.3

Table 6
FLAX YIELDS 4 YEAR AVERAGE TONS PER ACRE

Soil Dept. - Ore. Agr. Exp. Sta.

	Ave. Irriga. in inches	1930*	1932	1934**	1935	Total	Average	Gain by irr.	Gain by fert.	Gain by irr. & fert.
				Tons per acre						
Dry										
Check		1.95	.77	2.20	.94	5.86	1.47			
K (Potassium)		2.36	.72	2.94	.76	6.78	1.70		.23	
NK (Nitrogen-Potassium)		4.12	.92	3.00	.82	8.86	2.22		.75	
NKP (Nitrogen-Potassium-Phos.)		6.30	1.02	3.72	.88	11.92	2.98		1.51	
Light (Irriga)	3.25									
Check		3.14	1.20	2.64	1.62	8.60	2.15	.68		
K		3.62	.96	3.00	1.84	9.42	2.36	.66	.21	.89
NK		4.60	1.54	3.34	2.06	11.54	2.89	.67	.74	1.42
NKP		7.76	1.38	3.80	1.88	14.82	3.71	.73	1.56	2.24
Med. (Irriga)	4.87									
Check		3.24	1.94	2.86	2.16	10.20	2.55	1.08		
K		3.06	1.70	3.80	2.20	10.76	2.69	.99	.14	1.22
NK		5.50	1.60	3.76	2.56	13.42	3.35	1.13	.80	1.88
NKP		5.52	1.52	4.16	2.24	13.44	3.36	.38	.81	1.89
Heavy (Irriga)	6.50									
Check		3.89	1.48	2.66	2.08	10.11	2.53	1.06		
K		4.30	1.60	3.76	2.20	11.86	2.97	1.27	.44	1.50
NK		5.88	1.34	4.16	2.52	13.90	3.48	1.26	.95	2.01
NKP		6.44	1.64	4.16	2.48	14.72	3.68	.70	1.15	2.21
Average	4.87									
Check		3.05	1.35	2.59	1.70	8.69	2.17	.94		
		3.34	1.25	3.38	1.75	9.72	2.43	.97	.255	1.20
		5.03	1.35	3.57	1.99	11.94	2.98	1.02	.81	1.77
		6.51	1.39	3.96	1.87	13.73	3.43	.60	1.26	2.11

*This was a very heavy crop and might not have been thoroughly dry when weighed.
**Not air dry, perhaps irrigated plats were less dry.

Table 7
EFFECT OF 4 YEARS IRRIGATION ON FLAX
1930-32-34-35 - Soil Dept. Oregon State Exp. Station

Year	Irrigation in inches	Yield per acre		Increase from irrigation				Net profit Whole Crop		Gain in Net Profit by Irrigation
		Dry	All Irrigation Trials	Gain per acre	Gain Per A. inch	$ per acre $	$ per acre in. $	Dry	Irrigation	
		tons	tons	tons	tons	$	$	$	$	$
1930	3.	3.68	4.83	1.15	.38	28.75	9.58	52.00	70.85	18.85
1932	5.	.858	1.492	.634	.127	15.85	3.17	-18.55	-11.50	7.05
1934	6.	2.96	3.51	.55	.09	13.75	2.29	34.00	38.45	4.45
1935	6.	.85	2.17	1.32	.22	33.00	5.50	-18.75	.33	19.08
Average	5.	2.09	3.00	.9135	.204	22.84	5.14	12.18	24.53	12.35

Crop Valuation used $25.00 per ton. Cost of harvesting excess figured @ $6.00 per ton with water at $1.00 per acre inch.

The four year average yield on Willamette silt loam in the irrigation field at Oregon Agricultural Experiment Station follows:

Table 8

Treatment	Yield	Gain by Irrigation	Gain by Fertilizer	Total Gain
	Tons	Tons	Tons	Tons
Untreated	2.17	.94	-	-
Potassium sulfate	2.43	.97	.255	1.20
Potassium and nitrate	2.98	1.02	.81	1.77
Potassium, nitrate and phosphate	3.43	.603	1.26	2.11

Fiber yields were determined from these plats by Dr. B. B. Robinson (1934 only) shown in Table 9.

DISCUSSION

The potassium ion seems to be an especially important nutrient for fiber flax. It appears to give strength, to increase the length of straw, and to render plants more vigorous and disease resistant. This may be due to the action of potassium in keeping lower carbohydrates in solution until they can be translocated to the bast fibers where they are built into tissue. The potassium ion may aid formation of an enzyme or co-enzyme. It is suggested that this ion may also be helpful in formation of beet sugar and potato starch. Full returns may not be realized from potassic salts unless nitrates are also present to accompany potassium ion into the plant. A little phosphate may be helpful under some conditions as an aid to root development, and it should increase yield of seed flax.

The fertilizer requirements of fiber flax may be expected to vary with the soils and its previous cropping and treatments; however, potassium seems to be of first importance as to mineral nutrients needed. Nitrate may be more in demand for early vegetative growth and potassium most needed for fiber formation. This point is being investigated further. Fiber flax makes vigorous vegetative growth on muck soil, but the product is low in fiber content. Further studies are under way to test the value of potassic salts for overcoming this deficiency.

Better growth and yield may be expected when flax is planted very early under western Oregon conditions, and provided with a uniform, moderate moisture content. Since flax responds to a 16-hour day length, as reported by Redington and Priestly, it is suggested that the value of early planting here is to secure maximum growth during the longest days of the year, and before the field moisture is depleted. Providing a uniform supply of moisture and nutrient with the aid of supplemental irrigation should increase the length and prevent rapid ripening in order that pulling may be completed before the flax is dead ripe so as to secure a higher quality of fiber.

Table 9

Total Fiber in Pounds 1/10 Acre, 1934. Data by B. B. Robinson

No irrigation	46.72	No fertilizer	56.03
Light "	61.21	NK "	64.15
Medium "	68.15	NK "	61.24
Heavy "	71.01	NPK "	65.67

SUMMARY

Over half a million acres in Willamette Valley are suitable for fiber flax production.

Potassic salts with nitrogen supplied may be expected to increase length and value of fiber flax. The potassium ion may play a catalytic role in synthesis of carbohydrates, or function to keep simpler carbohydrates in solution until they can be deposited in the transforming bast fibers in the flax plant. Microscopic examination of stained cross sections show that potassic salts increase the plumpness of the flax fibers. X-ray studies show that fertilizers do not change the arrangement of the cellulose units of the fiber.

Supplemental irrigation has increased height and yield of fiber flax especially when used with fertilizers. One early five inch irrigation appears to be a suitable amount on Willamette Valley flax soils. Early planting and providing uniform moisture and nutrient supply with the aid of supplemental irrigation in western Oregon tends to delay the maturity and increase the length and value of fiber flax.

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