MOSAIC AND SPINDLE TO IN KINS S FOR TO FIELDS

by

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B. S. A., Mancas State Agricultural College, 1981

A THESIS

submitted in partial fulfillment of the requirements

for the degree of

MAST OF SCI CE

KANSAS S. TE AGHICULTURAL COLLEGE

1988

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HOSILIC AND SPINDLE TU IN KANSAS POTATO FIELDS

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Chester Eugene Graves

I O DCTION

Virus diseases have been present in the pointo grouing districts of this country for many years. Fotato seed growers have long realised that the control of virus diseases is one of their most difficult problems. These diseases enuse a condition commonly known shong the growers as "running out" of seed pointoes, hence they are diseased growersly as degemeration diseases.

Measic is perimps the most wide spread and domonly recognized of the point degeneration diseases. It is well known that a very high percentage of the points fields in the Horth contain more or less measic infection. Anneas point provers source their seed pointees each year from the Horth. It is very avident that much seed shipped into this state is grown from measic seed stook.

The most easily recognized foliage symptom of mossic, as expressed in the morthorm states, is a mottled chloresis in the leaves. The conspicuous absence of this leaf mottling in Kansas potato fields has caused considershile specific on as to how measile is expressed under our

conditions. It has even been suggested that the disease does not develop in Kansas hence does not affect the yield.

The purpose of these investigations, as far as potato mossic is concerned, has been only to study the mode of potato mossic expression in Kansas. The principal studies have been on plant characteristics, including size, shape, color and yield of mossic infected plants as compared with healthy plants.

Spindle tubes is a serious degeneration disease of the points that has not long been recognized. The avalindrical, pointed, or otherwise mischapen tubers that thermateries the symptoms argenered by this disease have been observed for several years by growers and others marking with points been. It has been noted that there tubers, mount to commarcial growers as "run out seed" or "had fingures," decrease the yield them used for seed.

However, it me not realised until recently that the causal factor for this condition is a filterable virus, and furthermore, that the introduction of this virus into healthy plant tissue will produce the degeneration disease that we now call spindle tuber.

with the startling discovery that spindle tuber is transmissible came the realization that there are many measibilities, in the natural production and management of a point crop, for the discemination of this discase. Contact of discassed and healthy cut ased pieces, intects feeding on discassed and healthy plants, contaminated tools such as cutting inives, pickers on the planter or other tools used for handling the points orop may all furnish possible means for discemining the causal agency of spindle taber.

With purpose of the investigations concerning spindle tuber has been (1) to study methods of dissemination, (2) to study the mode of expression in Kaness and (3) to determine the prevalence of visible spindle tubers in the seed pointees that are shipped into Kaness from other states.

The experimental data contained in this thesis are based upon three years investigations on measic expression (1924-1925-1926) and two years investigations on spindle tuber dissemination, expression and prevalence (1926-1927).

REVIE OF LIT TURE

The widespread interest in the virus discusse of plants began with the discovery by Mayer (1886) that tobseen measics is an infectious discuss. Iowanowski (1888) found that the filtered fluid from measic infected

Whe author is indebted to Dr. H. F. white for his valuable assistance and advice contributed during the progress of this work.

plants still possessons its infectious qualities. This opened the door to a no field in plant pathelogy; namely the field of filterable virus diseases of plants.

Deijerinek (1998) sworbed the same of tobacco mossic to a contaglous, aster soluble, non-corpusalar meterial which he colled "omtaguim vives fluidss," Woods (1902) contended that mossic is due to an oxidizing enzyme which enumes the destruction of chlorophyle

The immense account on work dans on messic transalasion leaves no doubt as to the infectious nature of the virus when transferred from diseased to healthy tierus in plants of the ame species. Furthermore, a great deal of evidence has been obtained which proves conclusively that cross-inconlations of measic are successful when the virus from infected plants of certain geners, fimilies or orders is introduced to certain plants of other geners, families or orders.

Elmar (1985) working with healthy tomato plants secured cross-infections with the virus from sugar owns, bean, crockneck squash, kimia, mlendula, volvet leaf, minkweed, estnip and martynis. He slave secured infection of the cow pee from ear plant, potato, coumber and orockneck squash. Formis plants because infected with the mossic wirus from coumber and erockneck squash while

the virus from infected colory and spurge plants was transmitted to outumbers.

Somults and Folsom (1923) worified the work of others on insect transmission of degeneration diseases of the potato in the field. Some of their findings on transmission, variations of symptoms and control measures are summarized as follows: "In Green Mountains, mild mosaic was not transmitted by contact except in stem and tuber grafts. In Green Mountains, aphids from a 'ourly dwarf' combination, apparently consisting of leaf-rolling mosaic and spindling-tuber together, transmitted the murly-duarf combination to a part of the hill and spindling tuber alone to the other part, distinction being made between different tuber units of the second generation. Natural transmission by insects contributes to the difficulty of the control problem. Hosaic symptoms from the same seed tubers show different complexes in different environments. Nottling is suppressed by southern regions and by higher temperatures. Dwarfing of the tubers, and therefore reduction in yield rate, me more pronounced in a southern region. Shading tended to increase mosaic mottling and to decrease leaf rolling. Selection of tubers without knowledge of the parent plants cannot eliminate seed from diseased plants infected late

the preceding season. Frankelty and heavy aphid infestation increased the spread of mild measis while sufficient isolation from diseased stocks reduced it so that a state of freedom from the disease was maintained. Isolation by 50 meters was insufficient, and over 400 meters was enfidemts²

Johnson (1097) working with elemetitantion of viruses reports eleven different messic virus eon tobacco and related plants. Nore than one virus may exist in a single plant. He found it possible to separate there on the basis of characteristic symptoms in infected plants.

Schults and Polson (1065) recognized four types of potato mosaic and classified them according to foliage symptoms. There four types are: (1) Elds mosie, which is characteristical by alar out motiling, some withking, ruffling mostic which shows diffused motiling and slight rolling upmard of the lastwa. Leafredl is distinguished from leafredling mossie by absence of dwarfing, rightly and chlorosis. (3) Rupese measic is characterised by semewhat diffused motiling, rupesity and distinct dwarfing, rubber redustion is more marked than in mild measic. (4) Orightly mosaic e million for a classical scheme in the class of the set of the se

mottling but is characterized by considerable wrinkling end ruffling.

Hartin (1962) was the first to apply the mame "spindle taber" to the long, sylindrical, misshapen tabers commonly known by growers as "run out seed." Schultz and Folsom (1963) definitely established the infectious meture of the dausal agency.

Sounts and Folson (1005) describe spindle taber symptoms as: "spindling stems and upright and somewhat darker green and mightly rugges and dwarfed folkage. Ahnormally spindling, spindle shaped and semanly dwarfed tabers with more or less completous and aparently missions syme are characteristics of this discase."

Cess (1983) describes spindle tuber folings as: "unually dimarked and excet, with fewer states per hill. The branches point upwards, and the leaves are small with many or ruffled margins. Affosted tubers are longer and more cylindician in shop than normal healthy tubers of the same variety, and are somatimes irregular and bumpy. The bud end of the tuber is more pointed and the tuber becomes spindle shaped. The eyes are more numerous, very shallow, and sensetimes even bulge out. In the red warleties such as Miss Triumph the color is much paler than normal and blotchy."

Werner (1980) in writing of the hubit of the spindle tuber plant says " "spindle tuber returds plant growth, when compared with normal plants, as manifested by a slower rate of plant emergence, low per cent of sprouting, and the development of small and less vigorous plants. Spindle tuber plants have an eroot bit of growth. The leaves are smaller and narrower than normal. They are folded up along the midrib and are wary along the margin. Spindle tuber has been found in all warteties tested (representing tem writety groupe). To instance of immunity or resistance us discovered."

Verner (1980) doubted that spids were responsible for transmitting the cusel agency of spinite tuber in western Nebreaks because there are few spids in that part of the state. Goes (1980), in a paper presented at the ninetsenth annual meeting of the American Phytopethological Society, reports that the transmission of this virus can be brought about by grueshoppers. Twenty-nine cases of infection were secured out of sixty-four incomintions. The plants incomined has inty.

Cose (1982) reports successful inculations of spinite tuber virus with a outting unife contaminated with juice from a spinite tuber which we used to out healthy tubers. Restly seed dices were successfully incuminated 10

by contact with the cut suriace of a spindle tuber.

In testing artificial means of transmission of spindle tuber, Folcon (1023), used tuber grafts. Be was successful in securing infections in 85 per cent of the trials. Leaf mutilations and stem grafts also gave infection to the degree that current season symptoms of spindle tuber were expressed by the progeny of the plants incealated.

Goes and Poitier (1985) found from their experiments that spindle tuber reacts to temporature conditions in the exact reverse to mossic. It was often impossible to distinguish plants affected with spindle taber when they were grown at low temperatures and the symptoms were increasingly edient as the temperatures were maised.

Normer (1986) reports greater elongation of spindle tubers at high temperatures in heavy sells of high molature content. Furthermore, infected plants grown under is vorable conditions produced better type tubers thun healthy plants grown under universible conditions.

MOSLIC STUDIES

Materials and Nothods

The investigations herein reported concerning mode of expression of mosaic in Kansas include data obtained

by tuber indexing and studying the progeny of 1,002 individual tubers which produced approximately 4000 plants.

The tubers used for these studies ware seared from the contin, Hinnesota, "orth Harota, umshington, Idsho, Haine and Hissouri. Host of the lets of seed recoived ware of inoum parentage. Some had been grown in Inset proof eages to insure against accidental infection. Others were obtained from fields known to contain heavy infection of messic. A few lots of seed were taken from commercial stoots on the market.

The following tables describe the working lots of seed used, their origin, the worksty, the infection carried and the index numbers given to the tubers in each lot of seed for the year the seed me planted.

Inde	ibe		: Intestion : Carried	: s Variety	i origin
1		76	: :Nomaic	s s Tril cam phon	: isconsin
81		141	flosale and \$Leafroll	i Burbanke	: slashington
1.42	-	165	: Gurly duarf	s s Tril um pho	s X dm ho
164 El R31 E46 L61		214 HRO R4O 出50 上70	: : :Nomic :Leafroll :Spindle tuber	t t tGreen them tein	t t t tilalne
815		314	:Unknown	: sumply Ohio	: :Narket
31.5		414	s Unknown	: Irish Cobbler	: :limricet

Table I. Seed for Monaie Studies - 1924

Ind	(ex	. No.	: Infection : Carried	t variety	i Origin
1	-	15	illosale	a Tradamophina	swinnesota
10	-	27	ilional c	:Triumphe	:Wisconsin
28	-	42	: Mosale	i Trinmpho	: illinnesota
43	-	50	tSpindle Tuber	silountsine	sliorth Daisota
51		58	inosaic and Spindle Tuber	i tharly Ohio	i shorth Dakota
59		66	illosale and iSpindle Tuber	: Irish Cobbler	: :North Dakota
67		93	i iNosale	sEarly Onic	illasouri
94		119	i Mpsais	SITISh Cobbler	s 4Minsouri
120	-	309	Unimorn	t Harly Ohlo	i iliarice t
310	-	453	a Unieno wa	Irish Cobbler	i slimeleot

Table II. Seed for Mosaic Studies - 1925

Table III. Seed for Mosaid Studies - 1926

In	den	110.	: InTection : Garried	: Variety	t Origin
2	-	50	s Healthy	i ilrish Cobbler	: sMiinnesota
51	-	90	I INDERIC	I Irish Cobbler	: Minnesota

Sixteen lots of seed from different sources were used in 1924 and 1926. These lots of seed earlied mossic, lesfroll and spindle tuber. A earchul study of the procesy of each tuber mas made in the greenhouse and in the field in order to become acquainted with the mode of expression of these diseases. In 1986 only the Irish Cobbler wristy mes used because this wariety is the principal one grown in the commercial districts in the state. This seed an selected in Minnesota from a field that contained a high infection of Messic. Forty tubers from messic infected hills and firty tubers from apparently healthy hills were jurnished by A. G. Tolkas, in dimme of Fotato Seed Certification work in Minnesota.

<u>Fuber Indefing</u>: In order to seeare data on the progeny of each individual tuber an indexing system was used. This work consisted in numbering each individual tuber. The index number of each tuber we inscribed on the tuber with India ink. The plants produced by each tuber unit wave staked, both in the greenhouse and in the field, such stake carrying the index number of each tuber unit.

<u>Greenhouse Studies</u>: Provious investigations by several workers show that measic folings symptoms show most distinctly on plants that are grown at ool temperatures and in diffused sumlight. Therefore, it was though t advisable to produce one plant from each tuber in the greenhouse where these conditions could be obtained,

For the greenhouse study, one eye was out from each tuber and planted in a 5 inch pot. The pot was given the 140

index number on the tuber from which this eye was taken. The remainder of the tuber was stored for field plantings. As soon as the plants in the greenhouse were large enough to express foliage symptons notes were taken and recorded. No yield date wave taken in the greenhouse because the pots were too small to secure normal yields. The object of the greenhouse study was to determine which tubers earled the messis wirms and which ones wave healthy. This was messessary because undar the intense sunlight of field conditions the boling symptoms are often masinds.

<u>Midd Studies</u>: The portion of the taber waved from taber indexing study in the greenhouse was used for making a field study of measie. Each taber still carried the index maker given it before the greenhouse planting were made. These tabers were out into from two to four seed pisces which constituted a "taber unit." Nach taber unit was planted in a short row of from two to four hills and was stated, the state earrying the index maber of the taber from thich the taber unit wave.

When the plants in the field wars about tan inches high the first field notes were bicen. The foliage of each tuber unit we inspected carefully to determine the symptoms expressed, A record was made indicating the symptoms expressed by each tuber unit. Field notes were taken a second the when the plants were in bloom. The 15

third set of field notes was taken when the tabors were harvested. Such tabor unit was harvested and the progeny weighed separately in order to compare yields of diseased and healthy tabor units.

In order to shorten the mork of taking notes and to make it possible to formulate tables describing measic folings symptoms a system of abbreviations was used. The letter used describes the symptoms expressed on the folings of plants grown in the greenhouse or under field conditions.

Key to Abbreviations Describing Folinge

- H Healthy Appearance
- H Hild mosaic Nottling only
- HE Rugose mosaie Rugosity and mottling
- LN Lesfrolling mossic Lesfrolling and mottling
 - L Leafroll only

EXP I LAL ZA

Utilizing the methods just described, studies wave made of the mode of expression or messic by plants and by the programy of the various lots of eeed obtained. The results of these studies follow. In presenting the data each lot of seed is breaked separately for the year in which the work was done.

The following tables show the number of tubers

expressing each type of mosaic or other symptons when planted in the greenhoure, and the subsequent expression of symptoms by progray or these same tabors when grown under knews field conditions.

Investigations, 1984

uable IV. Blies Triumphe from "icconsin Froduced in a Field Heavily Infected ith Messie. Inder Ho. 1 - 76.

Greenhouse	1		una	1		1	Ju	thill			
terah 27	1	2	2 8 8310	8 8 1 (1) (\$ 1]_	a adi	1 810	I I MM	1	2.1.	:yield
G Tubors Fild Mosaic		8									1163
67 Tubers Ruggeo Mosalo	13	182	1 12	1 39	12	1 12	13	1 13	1 202	8	1113

Table V. Reset Burbank Tubers from a Field in Unshington Containing a High Infection of Mossic and Leafroll. Index No. 81 - 141.

Greenhouse	173	.010 J	saill						
Symptoms	8 8王	1		I I				S 3 3 S AN 2 LM 2 L	
15 Tubers	18	\$ 12	1	:3	13	16	8	8 8 8 8 85 84	s s ilone
11 Tubers Mild Mosmic	1 22	1 22		24	1 13	3	1	1 1 3	1
11 Tubers Rugoso insaic	1 5	3	1	3 11	1	1	8	1 1 1 1	1 1
4 Tubers Leafroll osale	3	8	3	1 24	8	1	8	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1 11
/ Tubers Leafroll only	: 3	3	1	\$ 1]	13	8	1	1 11 16	3 10

Oreenhouse	5113		15		:000	11/1		e		-0110	ihill 60
Symptome	8	1	2	1	1 EL	: 811	2 2 22	1	1		sylold soundes
9 Tubors	12	3 1	1 8	27	2 2	E E	: 3	1	8 17	1 52	: slione
& Tubors	11	1	1	1:5	1	1	1	1	13	:1	1 11
3 Tubera Leafroll Only	1 12	1	:1	1	1 8	1 1	1	3 8	1 11	1 52	E 17
E Tubers Russe lessic	1	:1	1	11	î Z	-	2	1 2	: :5	: :2	i w

T le VII. Green Koun ins from Maine Carryin Infection of Mid sceie, Euroco Mossie, Lesicolling Mossie, en roll and Spindle fuber. I dex o. 164 - 214. H - HEO; SJ - R40; M40 - SJ - 1 - 100.

are house	1 leid S. ptoma:lield "ymptoms Jun 1 : Jun 15										
Sympto a roh 27	5 9日	8 812	3	1 1	SL.	t tH	3 272	1	1 11		tyleld
lealt y			1 11	19	12	1	:1	:1	18	:9	:133
13 Tubors	1	ة 17	1 2-6	12	-	\$ =1	16	1 14	1	1	10
13 Tubers Ragaso Mosaic	3 5	\$	1 18	2	8	3	2 8	1 :17	1	8	s s 63
& Tubers	8	3	1	1 14	1	1	8	1		1	: 13
15 Tubers Leafroll Oply			8		\$	1	1	1 8	1	1	\$

Le.

rable VIII. -marl, dos .rom Harket Stock Infoction Unknown. Index No. 215 - 314.

Treenhouse	11d e.	ideld toms: Held Symptoms : Jrel : JrelS							
Symptoms Harch 27	: : K	\$ 1 11	-	3 1 71	I H	1 (01	: ounc s		
7 Tabors	* 7	1	2	1 7	1	3	: 192		
5 Tubors Mild josaic	:1	1 4	:	: 3	: 2	5	: 15}		
1 Tuber Rugose	1	:1	1	: 1_	:	2	: 9		

* 106 tubors were indexed in the greenhouse. Only six tabers showed measic symptoms. Hese, toget or with seven healthy tubors were used tor i.ed. Dianting.

Table IX. "I ish Cobbler Seed from 'ar'st Stock. Infection Unknown. Index No. 315 - 414.

Greenhouse	1110	hill				
Symptoms rch 27	1 2 E	2 2 11	1 101	3 8日3	N 1	iyi ld
7 Tub rs Healthy	\$ 7	1	2	: 7	1	: 25
1 Ruber Mild Mosaic	3	: 1	:	:1	1	: 22 2

a 100 tubers were indexed in the greenhouse. Only one plant showed a very light ior of mild mossic. his tuber and seven healthy tubers were used for field minime.

Investigations, 1925

Table X. Bliss Triumphs from Jones Bros., Fitt, Minnesots, from a Field Wontsining a High Infection of Bosaics, Index So. 1 - 15.

Greenhouse	31	101	d Syn	nptoms 15		d Symp June	5	shill
March 29	2	Į.	1 2 16	: RM	; H	: N :		iyield :ounces
2 Tubers Healthy	1	2	1	:	: 2	1 1		1 6 <u>0</u>

Greenhouse	1510	ld Si May		s sPiel	June	3	shill
Symptoms March 29	1 1 11	1 1 H	s RM	1.11	1 H		iyield sounces
10 Tubers Hild Mossic	1 1	19	1	1 7	1 5	1	1 3
3 Plants Rumose Mosaic	1 1	3	1 8	1 1	3	1 2	: Sh

Table XI. Bliss Triumphs from $J_{\rm e}$ W. Brann, Madison, Missonin, Parent Held Showed High Messic Infection. Index No. 16 - 27.

Greenhouse	11101	d Sym Nay 1		201.07 2	June		shill
Symptoms March 29	2 2 H	1	I RM	ま ま.出	2 M	2 2 R00	iyield tounces
3 lubers Spindle Tuber	18	11	8	1 2	11	1	1 5 2/3
3 Tub re Mild Mosaic	1 1	12	1	1.1	: 2	8	1 42
6 Tubers Bugose Mosaic	11	1 4	11	1 8	14	8	1 8 1/3

Table XII. Bliss Triumphs from Sid Mason, Williams, Minnesota, from a Field Showing Only Light Masaic Infortion. Index No. 88 - 42.

Greenhouse	1110	d S		IFIG.	Id Sym June	ptom 3	:hverage
Symptoms March 29	1 11	2 2 11	I RM	1 1 E	3 8 15	E RIE	tounces
11 Tubers Healthy	1 11	3	8	: 11	3	8	3 7
4 Tubers	11	1 5	8 5	: 3	11	1	1 42

Table XIII. Green Mountains from H. L. Boley, Pargo, North Dakota, from a field Containing High Infection of Mossie and Spindle Tuber. Index Ho. 43-30.

Greenhouse	1110		ptoms 15	ille i	d Sym	ptom S	shill
Symptoms March 29	8 0 H	5 H	s RM	1 8 H	1 1 31	I RM	:yield
2 Tubers Healthy	: 8	1	1 3	12	8	3	Hone
4 Tubers Mild Mosaic	1 3	11	8 8	1 3	1 1	1 8	3 =
2 Tubers Rugose Tosal e	1	1 2	8	1	18	1	1 11

Table MIV. Early Ohios from H. L. Bolley, Pargo, Borth Damota, from a Field Containing a High For Gent of Mossis and Spindle Tuber. Index No. 51 - 28.

Greenhouse	May 15 s June 3						shill
Symptome Narch 29	8 8 H	1 8)]	a Rat	8 H	1 1 H	I RH	syield sounces
S Tubers Healthy	1 3	3	1	1 3	8	1 8	1 1 14
4 Tubers Mild Messic	8 3 3	1 3	8	11	: 5	8	\$ 7
1 Tuber Rugges Mosald	8	3	1 1	ŧ 2	8	1 1	8 3 4

Table XV. Irish Gobblers from H. L. Bolley, Farge, Horth Daiota, from a Field Containing a High Fer Cant of Hosaic and Spindle Tuber. Index No. 89 - 6.

Ore enhouse	ible.	ld Sy		sile	Id Sys June	ptom	shyerege
Symptoms March 29	8 2 H	3 I II	I RM	8 8 H	1 H	a RM	iyleld
6 Tubers Healthy	1 6	1	8	16	1	8	1 14
E Tubers Mild Lossie	1 2	1	2	1 2	1	1	8 8 0

Table XVI. Early Ohios from J. T. Cuinn, Columbia, Hissouri, from a Hield that Showed 3 Per Cent Monaic. Index No. 67 - 93.

Greenhouse		d S Nay			d Syn June		shill
Symptoms March 29	8 8 H	2 2 []	1 100	1 H	2 3 II	3 RM	'yield sounces
22 Tubers Healthy	1 17	1 4	81	\$ 17	: 4	:1	8 6
4 Tubers	3	1 4	1	111	: 3	8	1 4
1 Tuber	1	1 1	1	2	1 1	3	1 3

Table XVII. Irish Cobblers from J. T. Cuinn, Columbia, Missouri, from a Field Showing a Very Scall Per Cent of Nosmic Infection. Index Ho. 94 - 119.

Greenhouse		d Sym			d Syn June		il.verage shill
Symptoms March 29	8 1 H	1 1 11	8 3 RM	3 3_H	1 8 M	3 3 RM	iyield sounces
25 Tubers Healthy	1 23	1 2	8	1 25	2 8	3	3 7
1 Tuber Mild Mossic	1	1 1	8	111	2	1	1 3

Table XVIII. Early Ohios from Market Stock. Infection Unknown. Index No. 120 - 309.

Greenhouse	illeld Symptoms: Field Symptoms: Aven i May 15 : June 3 thill						
Symptoms Maron 29	t H	5 11	z BM	8 8 H	8 3 M	2 2 HII	iyield
10 Tubers Healthy	1 9	11	2	: 10	3	3	1 None
11 Jubers Mild Mossie	1 2	1 9	1	: 5	3 6	8	3 10
12 rubers Bugoss ogaic	1 3	3 6	1 5	11	1 10	11	1 10

Table XIX.	Irish	Cobb1	BIG	120	m Commercial	Stocks .
Infection Unknown	. Inde	an No.	310	-	453.	

Greenhouse	10101 1		toms.5		d Syn June	shill	
Symptoms March 29	1 H	I H	S RM	1 2 H	1 1 11	S EUL	:yield
10 Tubers Healthy	18	: 2	1	: s 10	1	3	1 42
4 Tubera	8 1	8 2 4	1 1	1 2	: 2	1	1 41
12 Plants Racose Hossic	1 7	1 2	1 3	1 9	8	: 5	1 4

Investigations, 1926

Table XI. Irish Coblers Selected by A. C. Tolans, St. Paul, Hinness ta, from Heens-free Hills in a Field that Contained a High For Cant of Messics. Index No. 1 - 50.

Greenhouse	I Hay 22 : June 4 this						
Symptoms April 5	8 8 (E)	1 8 H	2 2. 1010	I I H	1 3 M	s syleid s RM sounces	
38 Tubers Healthy	1 38	1	1	1 38	1	1 5 1 1 112	
5 Tubers	1 8	1	1	1 5	:	1 1 8	
7 Tubers	3	1 5	: 2	8 1	1 7	1 1 1 1 4h	

Table XXI. Irish Cobblers Selected by A. C. Tolass, from Mosaic Infected Hills. Index No. 51 - 90.

Greenhouse	11101	d Syn May 2	iptoms 2		d Sym June	thill	
Symptoms April 5	I H	8 8 M	E RM	1 1 []	3 H	E E REE	tounces
26 Tubors Hild Mosaic	1 21	: 5	8	: 23	: 5	2	1 6
14 Tubers Russes Moneic	1	1 8	1 6	8	1 8	1 6	i sh

DISCUSSION

the folloge symptoms appressed by the three different types of messic studied when grown under conditions favoroble for the disease, as were present in the greenhouse, are as follows:

 <u>Bild Mornic</u> -- Nothing of the leaves into fairly well defined light and dark green patches. Often the leaves are slightly wrinkled and more or less dwarfed.

8. https://www.com/noisestancesta

3. Losirolling messio -- Expressed by a rolling upmard of the leaves, may be distinguished from wrinking due to the prominences in rupper messic being of equal height and the depressions of equal depth, while with ordinary wrinkling the depressions and prominences are unoqual in depth and height.

Expression of the folings symptoms of these types of momais in the field may be the same as are expressed in the greenhouse especially 11 cool and eloudy weather persists. However, as soon as paried of intense smallph and high temperature prevails the symptoms usually damage.

These symptoms apparently wary with the type of

meanic carried by the plant and with the wariety. The usual dranges in symptoms in Iriah Gobblers, as the growing season progresses are: (1) making of the motiling in the case of mild means and (2) less of rugesity in the case of rugese means leaving only the motiling. In some cases both rugesity and motiling are masked and the plant is apprently healthy.

In the case of the warly thic, motiling is not masked as frequently as with the Iriah Oobbler. There is, horever, a strong tendoney toward massing as the seamon progresses. The damages in rugose measic symptoms in the marky thic is toward loss of rugosity and in some cases motiling is masked.

The behavior of the Biles Friumph variaty as regardes making of symptoms of mild meanls is prestically the same as in the Early Gilo. Tuber units that expressed typical rugges messic symptoms in the greenhouse often exhibited the symptoms of leafrolling meanle in the field. Probaby both leafrolling meanle and rugges meanid wave present in certain taber units but only rugges symptoms wave recognized in the greenhouse because leafrolling symptoms are suppressed by shading. Throughout the sense the Green Hearbith variety expressed marks symptoms the mast consistently of the waristics studied, in each case the symptome expressed in the greenhouse wave also

exhibited in the field by a large propertion of the tuber units. This was especially true in the case of rugose messic and leafrolling messic.

The following tables summaries the date obtained on each writely that was grown in the experiment for the entire three yoars. These tables show the number of taber units that produced healthy plants or expressed the different types of meanic in the grownhouse. The tables lies show the number of elseter plants from the same taber unit that expressed symptoms of each type of meanic during the subseconst cruthum second in the field.

Table XXII. Irish Cobbler Variety Comparing Poliage Symptome Expressed in the Greenhouse and in the Field.

	s Flo s Plan	ta 10	high	: Fleid Symptoms : Flants in bloom				
Greenhouse Symptome	8 8 III	8 8 H	3 3 RM	8 H 1	II.	s RH		
86 Tubers Healthy	1 88	1 4	8	1 3 86 1		8		
39 Tubers Mild Momaic	1 86	: 13	8	1 34	5	1		
33 Tubers Bagoso Mosal o	8 7	1 1 15	1 11	8 9 1	18	1 6		

Greenhouse Symptoms	a Plan	its 10	high	: Field Symptoms : Flants in bloom			
	2 2 H	8 8 12	a Rai	\$ \$ E	8 2 M	1	
32 Tubers Healthy	1 27	1 6	1 1	1 87	1 4	11	
13 Tubors Wild Mosaic	1 2	: 11	8 8	1 5	: 8	8 2	
3 Tubers	2	1 8	8 1	1 1	5 3 1	1 1	

Table XAIII. Early Ohio Variety Comparing Roliage Symptoms Expressed in the Greenhouse and in the Field.

Table XXIV. Blies Triumph Variety. Comparing Foliage Symptome Expressed in the Greenhouse and in the Field.

Greenhouse Symptoms	: Field S tons : : Plants 10" high :						Field S ptoms Flants in bloom				
	2 1 日		E RIES	LHI	L	2 2 H	8 2 14		LE :	L	
22 Tubers Healthy	1 15	8		7 8		: 13	1 1	8 1	7 1	2	
27 Tubers Mild Mosaic	18	: 14		4 2	1	1 16	1 6	8 1	1 1 1	1	
SE Tubers Rucose Mosal o	1 7	: 27	7	39 z	2	1 5	1 1 39	1 5 1	27:	6	

Table XXV. Green Mountain Wariety. Comparing Poliage Symptoms Appressed in the Greenhouse and in the Field.

	: Field Symptoms : Field Symp : Plante 10" high : Plants in b									
	1 1 1 11 1	н		Lit	L	1 1 1 II 1	11.1	1 ID 1	LHI	L
	1 28 1	4	1 1 1	9	2	: 25:	1	1 1 1	8 1	9
17 Tubers Hild cosic	1 3 1	8	1 4 1	2		1 4 1	7	1 4 1	2 1	
21 Tubers Rucose Mosaic	1 1	3	: 18:			8 1	2	1 171	2 1	
4 Tubers Leafroll Mosaie	2 2 2 2		2 1		1	2 1	5	8 1	4 2	-
13 Tubers Leaf roll Only	1 1		8 1	4		8 1		3 3	3 1	1

The bubber symptoms expressed were a decrease in size and number, hause a decrease in yield per hill. A review of lables IV to XXI shows that the average yield per hill of healthy tubers was greater than that from tubers carrying mild measic, reuges messic, leafrolling measic or leafroll.

Hild mossic reduced the yield per hill from ten to fifty per cent. August mossic usually decrement the yield from fifty to seventy-five per cent. This was true where folings symptoms were maxied as well as where folings symptoms were not maxied. Lesfrolling mossic often caused early death and very few tubors were produced on hills that survived.

SPINDLE TUBER STUDIES

Materials and Methods

The investigations herein reported concerning the transmission, expression and prevelence of spindle tuber include data obtained from two sears study (1986-1987) of the dissemination, symptoms expressed and percentages of visible spindle tuber contained in various lots of commercial seed shipped into Kamasa from northern states.

The tubers used for these studies were obtained from the following sources:

- Spindle tubers from the Department of Botany and Flant Fathology, University of Hebrasha, for transmission and expression studies.
- Kansas spindle tabors selected from the general erop reised by Gass. Spoaker, Mansas City, Mansas, R. E. 60.
- Minnesota commercial seed. Selected for typical Cobbler type and apparently free from spindle tuber. These were used in the transmission studies.
- 4. Spindle tubers and good type tubers from commercial sood. This sood was used in studies on the expression of symptoms of spindle tuber.
- 5. Sack lots of connersial seed from various sources were used for determining percentage of visible spindle tuber being shipped into the state.

A. Transmission Studies

<u>1. Inset Resentation</u>: The object of these studies was to determine whether or not spindle taber is transmitted in the field by insets feeding on diseased and basithy plants.

<u>Notheds of Inpulation</u>: A good type apparently healthy Irish Gobbler tubbr was cut into four seed pieces with a sterile knife and planted in a short row. Closely surrounding these plants were planted a number of seed

pieces out from spindle tubers.

is a check, while good type apparently healthy Inish obbies tubor as out its four please with a starily mits and pixed why. Sood please from spindle tubors are planted a rounding these four seed pleases an insect proof eage of disease cloth was hullt over this check.

<u>S. ..rtitical hoselation</u>: The object of these experiments was to determine the har or not the spindle tuber consol agency is trunsmissile by artificial methods that simulate injuries produced by making and cheming insects.

(a) Contaminated Meedle Functures in Leaves and Patioles Simulating Insect Functures.

<u>Methods of Inseultion</u>! Seed places from apparently healthy good type takers were planted. When the plante were shout a foot high incomlations were made by inserting a sterile needle into a typical spindle taker infected plant and then puncturing the leaves and petioles of a healthy plant with the contaminate needle.

(b) Maccration of Leaves with Contaminated Fingers, Simulating Damage Bane by Colorado Potato Bestle in the Field.

Methods of Inogulation: Seed places from good type apparently healthy tubers were planted, when the plants 3De

ware about a foot high incould one were made by crushing the leaves of a spinkle tuber infected plant between the themb and forefingers and then immediately rubbing the contaminated fingers on the leaves of healthy plants, exerting just mough pressure to break the last spidermis. Thirty plants were tweeted in this manner.

3. Outling Knife Misseminstion: The object of these experiments use to determine whether or not the causal agency of spindle taber may be transmitted by contaminated cutting knifes.

Nothed of Inconlation: A good type tuber was halved lengthwise through the bud end with a starile hmife. One half was then out into two seed pieces with a unife that had just been used to out a epindle tuber. The sister half was out into two seed pieces with a starile kmife to save as a sched on the incomlated hmife.

The two seed pieces from the incoulted half ware planted fourteen inches apart in one row. The two seed pieces from the unincoulted sister half were planted just compete in the adjoining row.

In 1986 this experiment was repeated twelve time at the Chas, Speaker form at Lonses Gity and ten times in the experimental field at Manhattan making a total of forty-four hills of incomized content) and forty-four

uninoculated sister hills.

In 1987 this was repeated trains times in the experimental field at Monhathan making twanty-four hills of incoulated seed pieces and twanty-four unincoulated distor hills. 52.

<u>4. Discontantion by Contact of Gut Surfaces</u>: The object of these experiments was to determine whether or not the gut surface of a spindle tuber seed piece coming in contact with the cut surface of a healthy seed piece would exement the discuss to the healthy seed piece.

Nothed of Incomination: a good type tuber was halved lengtheds through the bad and with a starlie kmift. A spindle taber was then halved and the ireship out surface rubbed against the freship at surface of one-half of the good type tubes. The incominated half and the unincominated sister half were each out into two seed pieces with a storile kmift. The two seed piecer from the incominated half were then planted in one new and the two uninceminated sister quarters were planted just opposite in an adjoining row.

In 1986 this experiment was repeated twolve times at the Game. Speaker farm near Langes Gity and ten times in the experimental farm at Manhattan, making a total of forty-four incomlated hills and forty-four unincomlated sister hills.

35.

5. Trensmission by tuber grafts: Since Contact of freshly out surfaces (lves only a short time for infection to take place before the surfaces dry, a test mas planned whereby contact of out surfaces might be secured for a considerable length of time. Tuber grafting was the usume thereby this was accomplished.

Nothed of Inceniation: A sterils cork borer was used to eat a hale through a good type tuber. By manus of the cork borer a round plug was than out out of a spindle tuber and fitted tightly into the hole in the good type tuber. The whole tuber was then planted.

This experiment was repeated ten times as the Spenter fars at Kaness Gity and thirty-mix times in the experiments field at Kanhattan, making a total of fortysix trikin.

<u>6. Finitor Par Disculation</u>: The juke from out seed places after causes the planter bax to becaus wet. In order to test the transmissibility of spinile tuber virus from the wet also of the planter hopper, an experiment was planned whereby inseniation by this means mint be simulated.

Method of Inoculation: The juice from a spindle

tuber was expressed upon a clean board by rubbing its freshly att sur ace spon the board. god type tuber as then ent in half with a sterile knife. The out surface of one half was rubbed against the contaminated surface of the board. The other half was used as a check.

Each helf was out into two seed pieces with a storile inife, the inculited quarters being planted in one row and the unincul ted quarters just opposite in the adjoining row.

This experiment was repeated traine times at the spearer farm and fifthem times in the experimental field at Munhottan making fifty-four hills with incoulated material and fifty-four hills from unincoulated sister seed theose.

7. Injury from Contaminated Flanter Florers: The ploters on a potato planter often injure the sprouts on seed pieces. This experiment was planned to determine whother plokers that are contaminated with the julos from spindle tubers might irransit the virus to healthy seed pieces when the sprouts or injured.

Nothed of Incoulation: A good type tuber showing short sproats was solvabed for the asperiment. This tuber was halved with a storido imife. Anoulation was then attempted by piercing the sproats on one half with a sharp medic that had just been inserted into a guiddle

tuber.

The incominted in one row and the unincominated eleter hal the planted just opposite in an adjoining row to serve scheck.

This experiment are repeated six times at the Speaker Sums t wannes fity and mine times in the experimental field at Man. than, whing a total of fifteen thiss.

B. Spindle Juber Expression Studies

The mode of expression of spindle tabor was studied by planting used pieces from definite spindle tabors in a row beside spurently healthy good type tabors. Foliage symptoms were observed from time to time and the plants from spindle tabors were compared with those from mod type tabors.

At hervost records were taken on the progeny of good type tubers and spindle tubers to determine tuber symptoms and yield.

C. Spindle Tuber Prevalence Studies

The provilence of spindle tabor Wes studied by examining warkows lots of seed shipped into Kannes by Eau Valley pots to growers. The percentage of visible spindle taber in each lot of seed we detormined by making counts of tubers in several sacks of seed. Counts were made in seventy-four lots of seed.

EXPERIMENTAL DI TA

Utilizing the methods just described, studies ware made of the transmission, expression and prevulence of spindle tuber. The results of these studies are herewith presented in tabular form. Each year's work is presented separately.

Investigations, 1926

A. Treasulation Studies, 1986: The results of the transmission studies are shown in the following tables. These tables show the methods of inoculation, the number of plants used, the number of plants that produced spindle tuber progeny at harvest and the per cent of plants that produced spindle tuber prograys. Table I. Results of Inoculating Bealthy Seed Pieces with a Spindle Tuber by Various Methods. Marwested July 14, 1986.

	1	1 10. 02	IFer Cent of
	tio. of		: Plants
Method of Incoulation	:Plants	S. T. Proge	myss. T. Progeny
1. Insect transmission	4	1 1	1 25
1. Check plants in insect proof enge	1 4 1	1 0	; O
2. (a) Contaminated needle punctures in leaves and petioles	\$ \$ 50 \$	s 6 s	5 12 5
S. (b) Maceration of leaves with contem- insted fingers	8 8 30 8	8 5 0 5	1 2 0
Inoculated halves	2 44	: 2	\$ \$.5
S. Uninconlated halves used as checks	1 44	2 0	8 0
faces, Inculated	z 46 z	; ; ;	2 <u>.</u> 2 1
4. Uninoculated halves used as checks	1 1 44 8	1 0 1	8 8 8
5. Tuber Grafts	1 46	1 1 36	3 78.2
Inoculated halves	: 54	: 0	1 0
6. Uninoculated halves used for checks	\$ \$ 54 \$	8 0 8	3 5 0 5
7. Sprout injuries; Inoculated halves	1 16	1 1	s 1 6.6
7. Uninoculated halves used for theoks	: : 15 :	5 Q 5	1 1 1 1 0

There from hills that did not show current seeson symptoms of spindle tuber from the various methods of insochation were saved for planting in the greenhouse to determine whether or not they were carrying the spindle tuber virus but did not express either follage or tuber symptoms in the first semewation.

These good type tubers were planted in the greenhouse on October 25, 1926, and were harvested February 21, 1927.

This work is to be articled from the standpoint that no healthy checks were planted in the greenhouse to astermine what part of the infection was due to insect transmission in the field the previous sesson and what part was due to the artificial insulations.

			Results in					
10	Spindle	Tuber	Inoculated	Plants	liere	Grown	in	the
Gre	enhouse	, 1926.						

Method Used to Inoculate Parent Plants		: No. of : Plants :S. T. Proge	
2. (a) Contaminated needle punctures in leaves and petioles	: 31 :	s 10 s	: : 32.2 :
2. (b) Maceration of leaves with contam- inated lingers	: 16 :	1 1 1 1	1 1 31.2 1
3. Gutting Knife	1 1 59	1 17	t t 28.8
4. Contact of cut surfaces	1 1 59 1	1 1 3 1	\$ \$ 5.0
7. Sprout Injuries	: : 20	s s 11	: : 65.0

B. Expression Studies, 1896: Plants produced from spindle tubers were compared with plants from good type tubers of the same wurlety. The Irish Cobbler and the Early Ohio varieties were unde. The Joinge symptems of spindle tuber were expressed as follows:

- (1) Flants more or less dwarfed and erect growing.
- (2) The angle between the peticle and stalk is very acute.
- (3) Flants show rigidity and when bent over return quickly to an erect position.
- (4) Leaves slightly dwarfed and usually show a ruffled wargin.
- (5) Foliage usually lighter green than in normal minute.
- The tuber symptoms expressed were:
- (1) Slongated or pointed at the bud end.
- (2) Sumerous, shallow or bulging eyes.
- (3) Greatly decreased yield due to smaller tubers but not necessarily a smaller number of tubers.
- (4) Early Ohio tubers lighter red in color than normal.

Yield records were taken to determine expression in yield by spindle tuber infected plants as compared with healthy plants from the same strain of seed.

Lot No.		t Average Y s Spincle Tube: t 1bs.	leld Per H111 r: Good Type i lbs.
1	: 0.9	.43	1 .54
2	\$ 3.5	s	1 .60
3	1 5.9	1 .19	1 .02
6	t 8.5	· 23	8 1 .08
5	1 5.4	s s o75	1 1.56
6	1 3.6	: .32	: .8B
7	1 3.1	28	1
Average	: 3.8	: 37	1 .72

Table III. Yields of Spindle Tubers Compared with Good Type Tubers, Irish Cobbler Variety, 1926.

<u>C. Providence Studics, 1985</u>: A survey was made of several lots of sock purchased by Kanasa growers to determine the percentage of visible spindle tuber shipped into the stute by northern sock growers.

The following table shows the lot numbers of the seed from which the counts were made, the kind of seed and the percentage of spindle tuber found in each lot.

Table IV. For Cont of Spindle Tuber Contained in Various Lots of Sted Purchased by Kansas Fotato Growers in 1926. Irish Cobbler Variety.

Lot No.	Kind of Sood	For Cent Spindle Tuber
1	Certified	0.9
2	Commercial	3.5
3	Comparcial	3.9
4	Commercial	8.5
5	Commercial	3.4
6	Commercial	3.6
7	Commercial	3.1
8	Commercial	2.3
9	Commercial	13.3
10	Commercial	4+4
11	Commorcial	6.7
12	Germercial	5.9
13	Gommercial	8,08
14	Gommercial	2.07
15	Commercial	3.7
16	Commercial	3.0
17	Commercial	1.2
18	Commercial	3.4
19	Howegrown	0.0
20	Commercial	0.3
21	Commercial	2.9
22	Connercial	8.6

Table IV (Continued)

Lot No.	Kind of Seed	Per Cent Spindle Tuber
23	Gommercial	0.2
24	Commercial	2.7
25	Commercial	3.2
26	Commercial	1,2
27	Commercial	2.0
28	Commercial	1.8
29	Commercial	1.1
30	Certified	0.3
81.	Certified	0.3
32	Commercial	5.0
33	Commercial	0.8
34	Commercial	0.9
35	Commercial	1.3
36	Conmercial	1.3
37	Commercial	0.4
38	Commercial	3.4
39	Commercial	1.7
40	Commercial	4.0
41	Commercial	28
42	Commercial	3.2
43	Commorcial	5.4
44	Commercial	3.6
Average		2.9

Investig tions, 1927

A. Transmission Studies, 1987: The results of the transmission studies are shown in the following tables. These tables show methods of incoulation, the number of plants used, the number of plants that produced spindle tuber progeny and the percentage of plants that produced spindle tuber progeny.

Table V. Results of Inoculating Healthy Seed Pieces with Spindle Tuber by Heans of Otting Enice and Seed Piece Contact. Harvested September 2, 1987.

Esthod of a	No. of Plants	I Ho. of 1 Plants 1 S. T. 1 Progeny	: Per Gent tof Plants : S. T. : Progeny	
Cutting Knife I Inoculated halves	24	: 15	1 02.6	\$ \$ 54.3
Uninoculated in halves; Outting in the Check	24	1 1 2 1	1 1 8.5 1	\$ \$ 8
Contact of Cut i Surfaces; Inocu- i lated halves	36	: 21 :	8 1 88+8 1	8 62 .8
Uninoculated 1 halves; Contact 1 Checks	36	5 5 2 5	1 1 5.5 1	8 8

Second Generation Studies after Insect Framewission: Tubers were as ed from the healthy tuber main in the field that was surrounded by spindle tuber infected plants in 1966. Tubers from the healthy check that was planted in the insect proof eags and surrounded by spindle tubers were also eaved. The object of this test was to detarmine

what per cent of the progeny of the plants surrounded by spindle tabor in 1926 would produce spindle taber progeny in 1927.

Seed pieces from times tubers were planted separately in cages in 1987. The results obtained with the second generation are shown in the following table:

Table VI. Results in Second Ceneration them Progeny of Caged and Unamged Plants Produced in 1986 .ere Grown in Cages in 1987.

Parent Plants :		illo. of Plants 18. 1. Progeny	: Per Cent of : Plants :S. T. Progeny
1. Insect Trans- 1 mission from neared by plants 1		1 1 5 1	1 1 43 1
I. Check plants : in insect proof : cage :	8	5 O	2 3 0 2

<u>B. paperssion Studies, 1607</u>: In 1907 the foliage symptoms of spinlle tuber infected plants were similar to those described in the 1906 expression studies. The tuber symptoms were also similar; however, additional yield expression data were obtained. The results are shown in the following table.

		average Yield Per Hill		
Lot No.	: S. T. iin seed	: Spindle Tuber	Good Type	
1	1 2.2	1 1.0	1.33	
8	1 3.4	1 .31	1.61	
3	1 3.6	1 .48	1 1.36	
4	1 3.6	.41	1 1.36	
5	1 2.8	1 008	1.24	
verage	1 3.1	5 1 0.57	1 1.2	

Table VII. Yields of Spindle Tubers Compared with Good Type Tubers. Irish Cobbler Variety. 1927.

C. Prevalence Studies, 1927: Further studies on prevalence were made in 1987 to determine the percentage of visible spindle tuber shipped into Kansas.

The following table shows the various lots of seed and the per cent of spindle tuber contained therein:

Table VIII. For Cent of Spindle Tuber Contained in Various Lots of Seed Furchased by Kanass Potato Growers in 1987. Irish Cobbler Waristy.

Lot No.	beed to baik	For Cent Spindle Tuber
1	Gertified	1.7
8	Certified	0.7
3	Certified	1.0
4	Gertified	2.5
S	Certified	2.1
6	Certified	3.0

Table VIII (Continued)

Lot No.	Kind of Seed	Fer Cent Spindle Tuber	
7	Certified	0.6	
8	Certified	1.8	
9	Commercial	6.1	
10	Commercial	S. 5	
11	Commercial	3.2	
12	Commercial	6.8	
13	Commercial	6.3	
14	eField Inspection	0.K. 5.1	
15	Field Inspection	0. K. 9.6	
16	whield Inspection	0.K. 5.9	
17	"Field Inspection	U. K. 5.9	
18	"Field Inspection	U.K. 2.0	
19	ofield Inspection	0.K. 7.1	
20	"Field Inspection	0.K. 7.6	
21	wield Inspection	0.K. 6.9	
22	Commercial	1.3	
23	Commercial	1.7	
24	Commercial	1.7	
25	Commercial	11.1	
26	Commercis.1	5.6	
27	Commercial	9.0	
28	Commercial	11.0	

Table VIII (Continued)

Lot No.	Kind of Soed	Por	Cont	Spindle	Tuber
29	Commercial			5+6	
30	Cormercial			7.6	
Average				4.6	

The field inspections were passed for seed certification but the final bin inspection necessary for certification was not made.

DISCUSSION

Transmission of spindle tuber was assured by several methods of incomlation. Current season symptoms were obtained by incomlation of the parent tubers and by introduction of the juice from spindle tuber infected plants into growing healthy plants by various means.

Insects feeding on spindle taber infected plants in the field transformed the virus to healthy plants which became infected. However, not all of the progeny of the infected plants showed current secon suppress. This was shown by the fact that three out of seven apparently good type tabers, produced in 1996 on plants in the field that wars surrounded by spindle tabers, yielded spindle taber progeny in 1927. The progeny of healthy checks grown in the eage in 1986 and eurrounded by injected plants produced only good type tabers in 1987.

Seedle punctures simulating insect punctures yielded

twelve per cost spindle tabor in 1886. These plants were not grown under mages and no checks were used; therefore, it is impossible to tall exactly how much of the spindle baber obtained was ireg ordinary field insect transmission. The sciones points to very little insect transmission in the plot where the transmission studies were conducted. This is probable because the plot was planted with seed ploces from only good type tabors and in further substantinted by the fact that not one of the checks used in connection with obtain inscalations showed surrent seesen symptome.

48.

All inoculations by leaf smooration were unsuccessful as for as the securing of current season symptoms was concerned. Thirty plants were inoculated, but not one showed any sign of spindle tuber during the growing season or when the plants were harvested.

Catting infit incomintions were made with forty-four seed pieces in 1000. Only two plants or 4.8 per contributed current season symptoms of spindle tubor. These plants user harvested on July 16. None of the sheekn wore infacted. In 1007 the plants were allowed to stand in the field until September 2, or about six weeks longer time in 1086. There were treaty-four plants in the sporiment. of spindle tuber. The plants in the choice row also showed spindle tuber, indicating that the disease was present in one tuber before it was at for seed. Omitting these two plants there was still 54.3 per cent spindle tuber in the inculsted row.

Leaving the plants in the field for a longer period apparently allowed time for the disease to express itself during the current eesson.

In the greemhouse the second generation from exiting unife incominted seed in 1986 shawed 20.8 per cent spinile tuber infection. As providently noted only 4.5 per cent of the plants shawed current season symptoms in the first generation. In the greenhouse no sheeks were included from unincomized seed, hence no allowance is made for insect transmission in the field during the provides season.

Contast of frachly out surfaces of spindle tubers and healthy tubers gave evidence of some transmission in 1026 when forty-four trials were under and one plant showed current season symptoms. The checks showed no symptoms. In 1027 plants from the contast incoulated tubers were allowed to stand until September 8. Of these incoulstion trials G2.6 per cent were successful.

Out surface incoulation and outling while incoulation probably take place very frequently under field conditions. The symptoms, however, apparently do not become evident

for a considerable period following infection. The Namese arop is usually dug in July and the first half of August which no doubt accounts for lack of expression of current season symptoms in the fields.

Tuber grafting was the most efficient means of transmitting the disease for securing current season symptoms. Porty-wix incodections were made, of which thirty-wix or 70.5 per comit, were successful. The contact of the cut surface of the spindle tuber graft and the basility tuber is maintained for a considerable time and this is probably the reason shy a high percentage of infection was secured. See Fistes II and III.

Planter box inoculations were unsuccessful in all of the fifty-four trials made. The reason for this has not been determined.

Sprout injuries inflicted with a needle that had previously been contaminated by prioring a spindle tuber gave one suscess hill inoculation in fifteen trials. In the greenhouse the second generation produced 58 per cent spindle tuber progeny. No checks were used, hence it is not known how much insect transmission might have occured in the field.

The spindle tuber expression studies indicate that foliage symptoms are expressed by more or less dwarfed and erect growth, the angle between the peticle and the stalk

being very soute. Injooted plants show right typ the leaves show dwarfing and rafiling at the margins. See Plates IV and V.

The tuber symptoms are expressed by elongation, numerous shallow and bulging eyes and greatly desreesed yield. Hield records indicate that the weight of spindlo tuber hills is about one-shird to one-isilf that of hills from good type tubere.

The prevalence of visible spindle tuber in sood shippod into the state by Exness growers causes a greater loss than was heretofore imagined. The growers have begun to realise this in the last few years and are carefully sorting over their seed and throwing out the wisible spindle tuber. Soon are using cortified sood.

A comparison of the percentages of spindle tuber in certified and commercial seed indicate that the certified seed contains far less spindle tuber than commercial seed, this is due to the continuous regular out of spindle tuber infected plants in the field by certified seed provers.

SUIGARY

 All types of potato mossic studied express thramesires in decreased yields even though the infected plants show no mottling or other foliage symptoms under field conditions.

2. The measic symptome expressed on points plants often change as the season progresses. A plant showing rugoes nosaic early in the season may show only mild measic symptoms or the symptoms may be entirely maked by the time the glants are in blocs.

3. Mild mosaic symptoms are usually masked by the time the plants are in bloom.

6. Fridence was obtained showing that spindle tuber one be transmitted (a) by insects, (b) by containated cutting hives, (c) by contact of diseased and healthy seed pieces, (d) by tuber grafts, (c) by injuries inflicted to sprouts by containing the tools.

5. Spindle tuber expresses itself in top growth as follows: (a) Finnts are desried and very erect. (b) The angle between the petiole and the stalk is very soute. (a) Finnt is sigld and when bent over returns quickly to an erect position. (d) Leaves are desried and usually have slightly ruffled margin. (e) The color of the infected glants is usually a lighter grown them normal.

6. The yield from spindle taber infected plants is about 60 per cent by weight as much as the yield from good type tabers.

7. Counts made in various lots of certified and commercial potate seed show that certified used contains far less spindle tuber than does commercial seed. ó2.

BIBLIOGRA PHY

Barrus, K. F. and Chapp, Ghes. 1926. Noteo Diseases and their Control. Cornell Ext. Bal. 155:38-123.

ami erinek

1899. Uber ein Contagium Vivium Fluidum als Ursacho der Heckenkrankheit der Tabeksbiatter Centralblatt für Hact, stot Staff (Part 2).

Elmer, O. H.

1922. Hossic Gross-Incoulation and Insect Transmission Studies. Science N. 8, 41:370-372.

Elmer, O. E.

1925. Transmissibility and Pathological Effects of the Mosaic Diesase. Iowa State Agr. Exp. Sta. Heg. Di. 62.

Fernow, K. He

1925. Interspecific Transmission of Momaic Diseases in Plants. Cornell Agr. Hzp. Sta. Memoir 96.

Folsom, D.

1923. Potato Spindle Tuber. Ne. Agr. Exp. Sta. Bul.

Folsom, D.

1921. Potato Leafroll, He. Agr. Exp. Sta. Bul. 297.

Goss, R. u.

1986. Transmission of Potato Spindle Tuber by Qutting Enives and Seed Piece Contact. Phytopathology 16:299-306.

Goss, R. W. and Peltier, G. L.

1925. Further Studies on the Effect of Environment on Fotato Degeneration Discasse. Hebr. Agr. Exp. Sta. Hes. Bul. 29.

Goss, R. W. 1924. Effect of Environment on Potato Degeneration Discases. Nebr. Agr. Srp. Sts. Nes. Bul. 26.

Goss, R. W. 1925. Two Important Groups of Nebraska Fotato Discases. Nebr. Ext. Circ. 1256. "Iwanowski. D.

1892. Uber die Mossik grankheit der Tabakapflanse. Bull. acad. Imp. Sci. St. Fetersb. N. A. 3:67-70.

Jehle, H. A.

1926. Disastrous Effect of Hosaie on the McCornick Potato, Md. Agr. Map. Sta. Bul. 282.

Johnson, James.

1926. Some Points of View on the Flant Virus Problem. Phytopathology 16:745-751.

Johnson, James.

1927. The Classification of Plant Viruses. Wis. Agr. Exp. Sta. Res. Bul. 76.

Erants, F. A. and Bisby, G. S.

1921. Relation of Mosaic to Bunning Out of Potatoes in Minnesota. Minn. Agr. Rxp. Sta. Bul. 197.

emartin, W. H. 1922. "Spindle Tuber," a New Potato Trouble, Hints to Potato Growers. N. J. State Potato Assn., Wol. 8, Boo., 1922.

Wilayer, Adolf.

1886. Uber dis Mossikkrankheit des Tabaks. Die Landwirtschaftliche Versuchs-Stationem. 32:650-467.

Helson, Ray. 1922. The Occurrence of Protozoa in Flants Affected with Mosaic and Selated Diseases. Mich. Agr. Ray. Sta. Tech. Bul. 50.

Schultz, E. S.

1924. Uny Potatoes Bun Out. U. S. D. A. Farmers Bul. 1436.

Schultz, E. S., Folgom, D. and Bonde, R. 1926. Potato Degeneration Diseases: Matural Spread

and Effect upon Mield. Ms. Agr. Exp. Sts. Bal. 331.

Schultz, E. S. and Folson, D.

1925. Infoction and Dissemination Experiments with Degeneration Diseases of Potatees. Observations in 1925. Journ, Agr. Res. 301403-288. Schultz. E. S. and Polson, D.

1923. Transmission, Variation and Control of Certain Degeneration Diseases of Irish Fotatoes. Journ. Agr. Res. 25:43-115.

Stewart. F.C. 1924. Control of Leafroll and Mosaic in Potatoes by Isolating and Roguing the Seed Plat. H. Y. Agr. Exp. Sta. Bul. 382.

Tompkins, C. N. 1926. Influence of the Environment on Potato Mosaic Symptoms. Phytopsthology 16:581-607.

Merner. H. C.

1925. The Spindle Tuber Disease as a Factor in Seed Potato Production. Hebr. Agr. Exp. Sta. Res. Bul. 32.

Woods . A. Te 1902. Observations of the Mosaic Disease of Tobacco. U. S. D. A., B.?. L. Bul. 18:1-24.

Stuated but not read.

J6. Plate I.

Good type tubers used in the Spindle Tuber transmission Studies. Such tubers as these were inoculated by the various methods described.



Spindle tuber transmission by tuber grafts. A plug was out from a spindle tuber and fitted into the hole in a good type tuber.





A tuber graft and its progeny. The old seed piece did not decay and the graft from the spindle tuber still shows.



A spindle tuber infected plant. Note the erect habt of growth, the sharp angle between the peticle and the main stem and the ruffling of the leaf margins.





A healthy potato plant. Note bushy habit of growth in contrast to spindle tuber infected plant in Plate IV.