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MAINE AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF MAINE AT ORONO

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TABLE OF CONTENTS

EFFECT OF THE SYMBEX SYSTEM ON YIELD, QUALITY, AND TUBER SIZE DISTRIBUTION OF KATAHDIN POTATOES MAINE - 1979-81

L.S. Morrow and H.J. Murphy[1]

INTRODUCTION

Microbial inoculation of agricultural soil or seed is not a new concept for improving yield or quality of crops. In 1947, Allison (1) reviewed inoculation experiments with free-living bacteria for the previous fifty years. Most of the research to that date had been conducted in the Soviet Union. Allison indicates that probably the first published claim of beneficial inoculation was by Caron (6) in 1895. Caron obtained marked increases in the yield of non-legumes by inoculation with cultures of various organisms isolated from soils and composts.

Much of the research was centered around Azotobacter following the discovery of this nitrogen-fixing organism in 1901 (1). Until 1928, yield increases were inconsistent and several theories were advanced about the activity of Azotobacter inoculations. These theories involved the requirement for a favorable soil environment including such variables as nitrogen supply or proper pH. Allison (1) also noted that one study indicated that the addition of cellulose-decomposing bacteria enhanced the ability of Azotobacter to increase yields of legumes and non-legumes.

After 1928, the Soviets had more success with bacterial inoculants and certain factors were determined to be important. These included adequate lime, an available energy source, suitable temperature, good aeration, and adequate minerals. The addition of cellulolytic bacteria with Azotobacter usually was beneficial.

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One commercially produced soil inoculant, Symbex[tm2], has received considerable attention in articles in agricultural publications (8, 9, 10, 11, 15, 18, 19, 21). According to the product label, "Symbex soil inoculant provides the soil with an enzyme-microbe system which, when used as directed, will accelerate the decomposition of crop residue releasing plant nutrients already present in the unavailable form." Attributes listed include a buildup of plant nutrients in the soil and improved soil tilth. The active ingredients include the nitrogen fixer, Azotobacter chroococcum, the cellulolytic-bacteria Actinomyces thermophilus, "Mixobacteria cellvibrio," "M. cytophaga," and Bacillus subtilis (two billion per cc. total cell count) suspended in a carrier of enzymes, nutrients, and microbial metabolic activators.

Symbex has been shown (17) to accelerate the initial breakdown of straw under controlled laboratory conditions. Brown and Witty (4) inoculated soil with Symbex and significantly increased yields of potted lettuce and radish but did not affect field yields of spring wheat.

Results of trials with other bacterial inoculations in potato crops have shown successes (5, 13, 14) and failures (13, 16, 22). Since the soil environment plays a major role (2, 3) in the establishment of an inoculant population, then geographic location must be an important consideration. Bacterial inoculations which may thrive in one region of the country may not be successful in another region where climatic and soil conditions vary. With the recent availability of bacterial soil inoculants, it is important that these products be evaluated under different soil and climatic conditions.

This paper reports on three years of research conducted at Aroostook Farm; Presque Isle, Maine, to determine the effectiveness of "Symbex System" products for improving the yield and quality of Katahdin potatoes. These products included the following: Symbex,

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[2] "Symbex" is a registered tradename of AGRO-K Corporation of Minneapolis, Minnesota. The use of this tradename and others (Symbooster, Symcoat, and Symspray) in this report implies neither endorsement nor criticism of these products.

a bacterial soil inoculant; Symbooster, a non-inoculated soil additive containing nutrients for microbial development; Symcoat, a bacterial seedpiece treatment; and Symspray, a foliar applied plant food supplement.

MATERIALS AND METHODS

Symcoat and Symbex Trials

The experiments were carried out at Aroostook Farm; Presque Isle, Maine, on a Caribou gravelly silt loam soil. Plots in all years consisted of four 34-inch rows each 40 feet in length. Each treatment was replicated four times and arranged in a randomized complete block design. The preceding crops for each experiment were field corn in 1979, spring oats in 1980, and winter rye in 1981. Katahdin cultivar seedpieces were planted nine inches apart in all years with a two-row assisted feed planter. The special fertilizer attachment (12) applied the dry fertilizer in bands two inches to each side of and slightly below the seedpieces and allowed for rates or mixtures to be changed between plots. The middle two rows were used for data collection on emergence rates, percent stand, yield, and to obtain samples for tuber defects and specific gravity evaluations. At harvest, a 50-pound sample was removed from the plots, graded for defects, and sized on a mechanical sizer. A random twenty-tuber sub-sample was also saved for specific gravity determination by the weight in air and water method (20). Soil samples were taken before treatments and before harvest for pH, percent organic matter, and major and minor element spectrographic analysis which was conducted by the Soil Testing Laboratory, University of Maine; Orono, Maine.

1979 Trial. A list of treatments which were applied in 1979 is shown in Table 1. Soil samples were taken from each plot on May 16, following the first cultivation of the field. The fodder corn had been plowed down the previous fall. Plots which included lime in the treatments received 4400 lbs./acre of lime, which was immediately disked in on May 18. Symbex was applied the same day at

Table 1. Effect of Symbex System products on emergence rate of Katahdin potatoes in 1979.

Treatments[1]	Dates				
	6-14	6-18	6-22	6-29	7-11
No Lime	Number of Emerged Plants				
Symbex only	1	16	28	37	40
Symbex, 30 N (urea)	3	34	46	59	64
Symbex, 60 N (urea)	3	36	51	67	68
-- 75 NPK	5	40	59	68	71
-- 150 NPK	4	36	52	64	67
Symbex, 75 NPK	6	42	55	62	66
Symbex, 150 NPK	4	31	47	58	64
Symbex, 150 NPK, Symcoat	4	38	59	68	70
Lime					
Symbex only	2	25	34	48	50
Symbex, 30 N (urea)	2	40	56	70	73
Symbex, 60 N (urea)	2	30	48	63	68
Symbex, 30 N (NH_4NO_3)	2	28	42	51	59
Symbex, 60 N (NH_4NO_3)	4	45	60	66	70
-- 75 NPK	3	41	53	57	60
-- 150 NPK	1	38	58	64	66
Symbex, 75 NPK	4	38	55	60	66
Symbex, 150 NPK	4	38	55	62	68
Symbex, 75 NPK, Symcoat	6	53	71	70	72
Symbex, 150 NPK, Symcoat	9	52	69	80	83
-- 150 NPK, Symcoat	7	50	66	75	75
Waller Duncan L.S.D. (0.05)	N.S.	19	16	13	12

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

the rate of one gal./acre with a back-pack compressed air sprayer. The four nozzle hand boom had a spray swath of six feet and the pressure was 40 psi. Immediately following the Symbex applications, the plots were disked to incorporate the inoculant to a depth of approximately six inches. The final incorporation was made within one hour after the last Symbex application. On May 17, Katahdin seedpieces were cut and several bushels were dipped in a Symcoat solution (3 gm/liter) in preparation for planting. Untreated and treated seed were planted on May 24, with the following fertilizer rates: 30 or 60 lbs./acre of nitrogen from either urea or ammonium nitrate, and 750 or 1500 lbs./acre of 10-10-10-2 fertilizer.

Emerged plants were counted several times in June to determine emergence rates and the final stand count was made on July 11. Commercial cultivation, hilling, fungicide, and insecticide practices were carried out on the plots during the summer until vine killing on September 8. Soil sampling was on August 24, and all plots were harvested on October 4.

1980 Trial. Treatments utilized in 1980 are listed in Table 2. Oat stubble was plowed under in the fall of 1979 and soil samples were taken after the first tillage in May. On May 21, 2046 lbs./acre of lime were spread, one gal./acre of Symbex was applied, and seedpieces were treated with Symcoat powder (75 gm/100 lbs.). Symbex was applied at 40 psi with an applicator mounted on a tandem disk harrow which allowed immediate incorporation of the bacterial inoculant. The applicator consisted of four hollow-cone nozzles mounted on the front of the disk harrow which had a width of 11 feet. All plots were planted on May 22, and included the following fertilizer rates: no fertilizer, 75 lbs./acre of nitrogen from ammonium nitrate, and 750 or 1000 lbs./acre of 10-10-10-2 fertilizer. One gal./acre of Symbooster was applied to the plots of two treatments as a directed spray beneath the potato vines on July 8, using a two-nozzle compressed air sprayer at a pressure of 40 psi. The potato rows were hilled with a commercial potato cultivator following the Symbooster treatments. Foliar applications

Table 2. Effect of Symbex System products on emergence rates of Katahdin potatoes in 1980.

Treatments[1]	Dates			
	6-16	6-19	6-23	6-30
No Lime	Number of Emerged Plants			
Check - no treatment	10	36	71	86
-- 75 N (NH_4NO_3)	10	34	72	86
Symbex, 75 N (NH_4NO_3)	12	39	75	87
-- 75 NPK	12	44	70	85
Symbex, 75 NPK	10	34	66	85
-- 100 NPK	8	32	71	90
Symbex, 100 NPK	9	32	70	86
-- 100 NPK, Symcoat	36	73	84	92
-- 75 NPK, Symspray	13	43	72	86
Symbex, 75 NPK, Symspray	5	29	70	90
-- 75 NPK, Symbooster	8	32	69	85
Lime				
-- 75 N (NH_4NO_3)	15	41	77	87
Symbex, 75 N (NH_4NO_3)	13	41	70	89
-- 75 NPK	10	38	68	86
Symbex, 75 NPK	10	41	68	87
-- 100 NPK	13	33	63	84
Symbex, 100 NPK	11	38	70	83
-- 100 NPK, Symcoat	27	68	82	97
Symbex, 75 NPK, Symspray	12	37	73	89
-- 75 NPK, Symbooster	8	30	63	83
Waller Duncan L.S.D. (0.05)	13	14	10	N.S.

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

of Symspray were made with a compressed air sprayer at the rate of 0.2 qt./acre on July 8, July 25, and August 5.

Emerged plants were recorded regularly in June, and in addition, the number of stems was counted in August. Potato vines were killed on September 8, and soil samples were taken from all plots before harvest on September 29.

1981 Trial. The 1981 trial consisted of lime and/or Symbex applications either in the fall of 1980 or the spring of 1981, as noted in Table 3. Winter rye stubble was plowed down in August of 1980, and the field was smoothed with a tandem disk harrow before soil samples were taken from each plot on August 25. Lime was spread on the appropriate plots on August 26, at the rate of 3600 lbs./acre. One gal./acre of Symbex was applied with the tandem disk harrow and sprayer at 40 psi pressure and incorporated immediately. In early September, the field was seeded with winter rye. This was harrowed in the following spring prior to the additional application of Symbex and lime. On May 11, 3000 lbs./acre of lime were applied to one treatment and on May 22, one gal./acre of Symbex was incorporated with the tandem disk harrow and sprayer in two treatments. The plots were planted and fertilized on June 1, according to three rates: no fertilizer, 75 lbs./acre of nitrogen from ammonium nitrate, or 750 lbs./acre of 10-10-10-2 fertilizer. Earlier during the same day enough seed for one treatment was dipped in a Symcoat solution (1 gm/l).

Emerged plants were recorded on several dates in June and a final stand count was made on July 2. Vine kill applications were begun on September 18. Soil samples were taken on August 30, and the plots were harvested on October 1.

After sizing and grading, fifteen-pound sub-samples were placed in 50F storage. On February 25, they were weighed to determine water loss. The samples were weighed again, after removing sprouts, to determine loss due to sprouting.

Acid-Soil Tolerant Product Trial

In 1981, new formulations of both Symbex and Symbooster were evaluated in a field situation. The test was located on land which had been out of potato production for four years. The experimental design and plot size were the same as the test previously described. After land preparation, one gal./acre of Symbex or Symbooster (old and new formulations) was applied on May 21, with a compressed air sprayer and a four-nozzle hand boom at 40 psi pressure. Since the spray swath was six feet, two passes were necessary to cover each plot. Incorporation of the sprays was accomplished within 45 minutes with a tandem disk harrow. Katahdin seedpieces were planted nine inches apart with an assisted feed planter on June 1. Fertilizer was applied in bands at planting at the rate of 665 lbs./acre of 14-14-14-2.

Emerged plants were counted regularly in June and a final stand count was made on July 2. On September 18, a commercial vine desiccant was applied to the potato tops; and on September 30, the plots were ready for harvest. Yields of the center two rows were recorded and a 50-pound sample was saved for sizing and grading purposes.

RESULTS

Symcoat and Symbex Trials

Emergence Rate. Emergence rates in all three seasons, as indicated by the number of emerged plants (Tables 1 - 3) were affected by Symcoat applications to seedpieces. More treated than non-treated seedpieces emerged at early dates. The greatest increase in emergence rate occurred in 1980 and was due to an excessive application rate when compared to 1979 and 1981. In 1979, treatments lacking any fertilizer hindered seedling emergence; while in 1980 and 1981, seedlings in similar treatments emerged as quickly as fertilized seedlings. Seedling emergence was unaffected by lime, fertilizer rate, or Symbex applications.

Table 3. Effect of Symbex System products on emergence rate of Katahdin potatoes in 1981.

Treatments[1]	Dates				
	6-19	6-22	6-25	6-29	7-2
Fall	Number of Emerged Plants				
Check - no treatment	1	23	64	83	91
-- 75 N (NH_4NO_3)	4	32	68	84	96
Symbex, 75 N (NH_4NO_3)	2	31	69	88	96
Symbex, 75 N (NH_4NO_3), Lime	3	36	73	84	91
-- 75 NPK	2	29	62	83	93
Symbex, 75 NPK	2	26	67	82	90
Symbex, 75 NPK, Lime	4	36	70	88	93
Symbex, 75 NPK, Lime[2]	4	48	82	92	99
Spring					
Symbex, 75 NPK	2	26	65	86	97
Symbex, 75 NPK, Lime	0	21	60	83	91
Waller Duncan L.S.D. (0.05)	N.S.	13	10	7	6

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

[2]Symcoat treated seed.

Yield: Yield was not affected by Symbex applications in any of the three seasons (Tables 4 - 6), with one exception. In 1979, on limed plots, Symbex plus 150 lbs./acre of NPK produced significantly lower yield than 150 lbs./acre of NPK alone. Yields were 236 and 281 cwt./acre, respectively. In the same trial on limed plots, Symbex plus 150 lbs./acre of NPK with Symcoat treated seedpieces produced 270 cwt./acre, which was similar statistically to the plots where only fertilizer had been applied.

Higher fertilizer rates and more complete fertilizer mixtures produced higher yields in all years. In 1979, there was a statistical

Table 4. Effect of Symbex System products on total yield, usable yield, percent defects, and percentage of yield in two market grade sizes of Katahdin potatoes in 1979.

Treatments[1]	Yield above 1½ inches Cwt./A.	Usable[2] yield above 1½ inches Cwt./A.	Percent defects	Percentage of yield 1-7/8 to 4 inches	Percentage of yield 2-1/2 to 4 inches
No lime					
Symbex only	58	46	22.3	90.8	45.4
Symbex, 30 N (urea)	149	120	19.5	97.6	74.2
Symbex, 60 N (urea)	174	138	20.2	97.8	76.8
-- 75 NPK	186	160	14.5	97.2	70.6
Symbex, 75 NPK	217	189	14.3	98.2	77.0
-- 150 NPK	259	205	21.0	94.7	79.2
Symbex, 150 NPK	231	167	28.9	96.9	77.1
Symbex, 150 NPK, Symcoat	263	217	18.1	96.1	73.0
Lime					
Symbex only	98	82	17.3	94.8	69.4
Symbex, 30 N (urea)	164	134	19.3	97.4	78.2
Symbex, 60 N (urea)	146	105	29.3	98.0	78.8
Symbex, 30 N (NH_4NO_3)	131	107	18.4	97.0	77.6
Symbex, 60 N (NH_4NO_3)	193	159	17.2	98.5	78.8
-- 75 NPK	219	169	22.8	97.2	78.4
Symbex, 75 NPK	217	176	18.8	99.4	84.7
Symbex, 75 NPK, Symcoat	246	204	16.9	98.0	67.1
-- 150 NPK	281	224	20.3	93.0	80.1
Symbex, 150 NPK	236	188	20.3	96.0	78.3
Symbex, 150 NPK, Symcoat	270	216	20.0	98.5	80.0
-- 150 NPK, Symcoat	288	244	15.5	98.0	78.3
Waller Duncan L.S.D. (0.05)	37	41			

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

[2]Less defects (sunburned, misshapened, and growth cracked tubers).

Table 5. Effect of Symbex System products on total yield, usable yield, percent defects, and percentage of yield in two market grade sizes of Katahdin potatoes in 1980.

Treatments[1]	Yield above 1½ inches Cwt./A.	Usable[2] yield above 1½ inches Cwt./A.	Percent defects	Percentage of yield 1-7/8 to 4 inches	Percentage of yield 2-1/2 to 4 inches
No Lime					
Check - no treatment	134	131	1.3	89.8	15.4
-- 75 N (NH_4NO_3)	209	202	3.3	94.5	40.7
Symbex, 75 N (NH_4NO_3)	252	245	2.7	95.0	46.5
-- 75 NPK	295	288	1.6	96.0	49.4
Symbex 75 NPK	282	275	2.7	95.6	45.0
-- 100 NPK	326	311	4.7	95.5	64.5
Symbex, 100 NPK	327	311	4.7	97.0	60.6
-- 100 NPK, Symcoat	209	174	16.4	72.5	9.4
-- 75 NPK, Symspray	317	314	1.1	96.5	53.4
Symbex, 75 NPK, Symspray	283	279	1.5	96.5	47.5
-- 75 NPK, Symbooster	291	283	2.7	95.3	46.0
Lime					
-- 75 N (NH_4NO_3)	239	231	3.4	94.4	32.0
Symbex 75 N (NH_4NO_3)	241	231	3.8	97.1	57.1
-- 75 NPK	307	296	3.8	97.1	58.1
Symbex, 75 NPK	300	292	2.5	96.1	53.4
-- 100 NPK	327	304	6.9	96.5	58.6
Symbex, 100 NPK	326	318	2.6	96.6	62.9
-- 100 NPK, Symcoat	243	212	13.3	76.3	10.8
Symbex, 75 NPK, Symspray	298	282	5.5	96.1	55.9
-- 75 NPK, Symbooster	288	280	2.8	97.1	54.2
Waller Duncan L.S.D. (0.05)	38	35			

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

[2]Less defects (sunburned, misshapened, and growth cracked tubers).

Table 6. Effect of Symbex System products on total yield, usable yield, percent defects, and percentage of yield in two market grade sizes of Katahdin potatoes in 1981.

Treatments[1]	Yield above 1½ inches Cwt./A.	Usable[2] yield above 1½ inches Cwt./A.	Percent defects	Percentage of yield 1-7/8 to 4 inches	Percentage of yield 2-1/2 to 4 inches
Fall					
Check - no treatment	101	100	1.3	95.0	26.7
-- 75 N (NH_4NO_3)	206	189	7.9	98.1	68.9
Symbex, 75 N (NH_4NO_3)	207	185	10.8	98.1	63.3
Symbex, 75 N (NH_4NO_3), Lime	221	194	12.2	97.8	68.3
-- 75 NPK	250	228	9.2	97.6	64.0
Symbex, 75 NPK	244	223	8.4	98.0	69.3
Symbex, 75 NPK, Lime	235	207	12.6	98.3	68.5
Symbex, 75 NPK, Lime[3]	242	220	8.8	97.1	53.7
Spring					
Symbex, 75 NPK	258	230	11.1	98.4	70.2
Symbex, 75 NPK, Lime	234	213	9.1	98.3	63.2
Waller Duncan L.S.D. (0.05)	33	35			

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

[2]Less defects (sunburned, misshapened, and growth cracked tubers).

[3]Symcoat treated seed.

difference between 60 lbs./acre of urea and ammonium nitrate sources, 146 and 193 cwt./acre, respectively. Yields at the 30 lbs./acre rate for both nitrogen sources are not consistent with the results at the higher rate.

Yield was greatly decreased by Symcoat applications in 1980, but there was no effect in 1979 and 1981. Tubers produced in plots with Symcoat applications were of smaller size in all trials, as indicated by the decrease in the percentage of yield in the size class 2½ to 4 inches. The only exception to this was in 1979, where only one of the four Symcoat treatment plots showed a decrease in this size category. Other products tested in 1980, Symspray and Symbooster, did not affect yield.

Percentage of tuber defects was not affected by Symbex, Symbooster, or Symspray applications. Symcoat-treated seedpieces produced a greater than normal percentage of tuber defects in 1980.

Tuber Size Distribution

The tuber size distribution, as affected by treatments, is presented by the number of tubers produced (Tables 7 - 9) in each of six size classes. In 1981, there were no tubers produced over four inches in size, so there are only five size classes reported. There is no indication that Symbex, Symbooster, or Symspray applications affected the number of tubers in the six size classes.

The tuber number was affected in the plots which lacked fertilizer or had Symcoat-treated seedpieces. The non-fertilized plots produced fewer tubers in the 2¼ to 4-inch sizes in 1979, and 2½ to 3¼-inch size in 1980 and 1981. Symcoat treatments produced fewer tubers 2¼ to 4 inches in size in 1980, yet the number of tubers in size classes 2½ to 3¼ inches in 1979, 1½ to 2¼ inches in 1980, and 1-7/8 to 2½ inches in 1981 was increased. Generally, in Symcoat plots, tubers were smaller than the average in 1980 and 1981.

Table 7. Effect of Symbex System products on number of tubers in six size classes of the Katahdin potato in 1979.

Treatments[1]	1½ to 1-7/8 inches	1-7/8 to 2¼ inches	2¼ to 2½ inches	2½ to 3¼ inches	3¼ to 4 inches	Over 4 inches
No Lime						
Symbex	28	30	30	31	2	0
Symbex, 30 N (urea)	15	40	44	97	19	1
Symbex, 60 N (urea)	17	39	42	100	33	0
-- 75 NPK	21	59	58	115	26	1
Symbex, 75 NPK	15	62	53	129	37	1
-- 150 NPK	18	44	49	132	65	4
Symbex, 150 NPK	19	40	60	102	60	2
Symbex, 150 NPK, Symcoat	29	69	70	150	40	3
Lime						
Symbex	23	29	30	57	14	1
Symbex, 30 N (urea)	16	31	37	100	34	1
Symbex, 60 N (urea)	18	32	30	93	25	0
Symbex, 30 N (NH_4NO_3)	15	22	32	81	22	0
Symbex, 60 N (NH_4NO_3)	17	34	50	129	30	0
-- 75 NPK	17	45	47	121	38	2
Symbex, 75 NPK	8	33	38	136	45	0
Symbex, 75 NPK, Symcoat	23	60	99	162	28	1
-- 150 NPK	14	41	42	128	79	7
Symbex, 150 NPK	20	38	53	122	56	1
Symbex, 150 NPK, Symcoat	19	60	55	162	62	0
-- 150 NPK, Symcoat	22	57	73	184	53	1
Waller Duncan L.S.D. (0.05)	17	21	20	30	18	2

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

Table 8. Effect of Symbex System products on number of tubers in six size classes of the Katahdin potato in 1980.

Treatments[1]	1½ to 1-7/8 inches	1-7/8 to 2¼ inches	2¼ to 2½ inches	2½ to 3¼ inches	3¼ to 4 inches	Over 4 inches
No Lime						
Check - no treatment	73	183	88	25	1	0
-- 75 N (NH_4NO_3)	63	133	146	112	1	0
Symbex, 75 N (NH_4NO_3)	66	145	130	156	1	0
-- 75 NPK	73	158	130	149	10	0
Symbex, 75 NPK	75	173	148	155	3	0
-- 100 NPK	67	103	121	212	23	2
Symbex, 100 NPK	68	122	135	191	25	0
-- 100 NPK, Symcoat	279	234	79	27	0	0
-- 75 NPK, Symspray	72	175	159	190	7	0
Symbex, 75 NPK, Symspray	64	177	154	162	7	0
-- 75 NPK, Symbooster	84	174	170	156	2	0
Lime						
-- 75 N (NH_4NO_3)	75	184	182	108	15	0
Symbex, 75 N (NH_4NO_3)	45	94	114	161	3	0
-- 75 NPK	56	117	141	157	14	0
Symbex, 75 NPK	70	121	166	195	5	0
-- 100 NPK	69	141	142	178	26	0
Symbex, 100 NPK	72	118	125	203	19	0
-- 100 NPK, Symcoat	288	331	80	32	0	0
Symbex, 75 NPK, Symspray	70	148	140	169	9	0
-- 75 NPK, Symbooster	59	129	149	176	6	0
Waller Duncan L.S.D. (0.05)	29	69	50	47	22	2

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

Table 9. Effect of Symbex System products on number of tubers in five size classes of the Katahdin potato in 1981.

Treatments[1]	1½ to 1-7/8 inches	1-7/8 to 2¼ inches	2¼ to 2½ inches	2½ to 3¼ inches	3¼ to 4 inches
Fall					
Check - no treatment	28	94	83	33	2
-- 75 N (NH_4NO_3)	21	57	83	155	18
Symbex, 75 N (NH_4NO_3)	22	69	86	151	11
Symbex, 75 N (NH_4NO_3), Lime	24	63	84	166	17
-- 75 NPK	26	73	116	182	16
Symbex, 75 NPK	21	65	92	196	14
Symbex, 75 NPK, Lime	18	66	81	167	23
Symbex, 75 NPK, Lime[2]	38	99	136	160	8
Spring					
Symbex, 75 NPK	28	79	88	197	20
Symbex, 75 NPK, Lime	25	85	104	182	10
Waller Duncan L.S.D. (0.05)	13	24	26	34	11

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

[2]Symcoat treated seed.

Number of Tubers and Stems

A decrease in total number of tubers per plot (Tables 10 - 12) occurred in the non-fertilized plots. Total tubers per plot were significantly greater in Symcoat treatment plots in all three seasons. The number of tubers per hill was increased by Symcoat in 1981 and in one out of four treatments in 1979. The number of hills per plot was increased in one Symcoat treatment in 1979 and in the only Symcoat treatment in 1981. Stems were counted only in 1980 and 1981. The number of stems per plot and per hill was greatly increased by Symcoat in 1980, but not in 1981. Tuber and stem numbers either per plot or per hill were unaffected by Symbex during all three years, or by Symspray and Symbooster in 1980.

Tuber Quality

Quality of harvested tubers was determined by measuring the amount of external defects and an internal defect called hollow heart (Tables 13 - 15). External defects did not differ greatly among treatments in 1979 or 1981. In 1980, percent of misshapen tubers was higher in the Symcoat treatments, both limed and unlimed. Hollow heart, determined in 1979 and 1980 only, was not affected in 1980. Limed plots with nitrogen only or without fertilizer had a considerable amount of tubers with hollow heart in 1979.

Another quality factor is the tuber specific gravity. Specific gravity was not affected by Symbex or Symcoat in any season. Changes in fertilizer rate in 1979 and 1981 altered the density of harvested tubers, since corresponding increases in specific gravity were noted for decreasing fertilizer rates.

Soil Samples

Soil samples were taken before treatments were established and at the end of the growing season. Percent organic matter remained unaffected by treatments. Soil pH and availability of several elements were affected but only by lime applications.

In 1979, soil pH before treatments averaged between 4.9 - 5.0;

Table 10. Effect of Symbex System products on number of Katahdin tubers per plot and tubers per hill in 1979.

Treatments[1]	Tubers per plot	Hills per plot	Tubers per hill
No Lime			
Symbex only	125	40	3.1
Symbex, 30 N (urea)	214	68	3.2
Symbex, 60 N (urea)	233	68	3.4
-- 75 NPK	280	71	4.1
Symbex, 75 NPK	297	66	4.5
-- 150 NPK	312	67	4.7
Symbex, 150 NPK	283	64	4.4
Symbex, 150 NPK, Symcoat	361	70	5.2
Lime			
Symbex only	153	50	3.0
Symbex, 30 N (urea)	219	73	3.0
Symbex, 60 N (urea)	196	68	2.9
Symbex, 30 N (NH_4NO_3)	172	59	2.9
Symbex, 60 N (NH_4NO_3)	260	68	3.9
-- 75 NPK	270	60	4.5
Symbex, 75 NPK	260	66	4.0
Symbex, 75 NPK, Symcoat	375	72	5.3
-- 150 NPK	311	66	4.7
Symbex, 150 NPK	288	67	4.3
Symbex, 150 NPK, Symcoat	358	83	4.3
Waller Duncan L.S.D. (0.05)	55	12	1.1

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

Table 11. Effect of Symbex System products on number of Katahdin tubers, hills, and stems per plot and number of tubers and stems per hill in 1980.

Treatments[1]	Tubers per plot	Hills per plot	Stems per plot	Tubers per plot	Stems per plot
No Lime					
Check - no treatment	370	86	160	4.3	1.9
-- 75 N (NH_4NO_3)	455	86	187	5.3	2.2
Symbex, 75 N (NH_4NO_3)	498	85	205	5.9	2.4
-- 75 NPK	520	85	188	6.1	2.2
Symbex, 75 NPK	554	85	192	6.5	2.2
-- 100 NPK	528	89	191	5.9	2.1
Symbex, 100 NPK	541	86	190	6.3	2.2
-- 100 NPK, Symcoat	619	92	314	6.7	3.4
-- 75 NPK, Symspray	603	86	187	7.1	2.2
Symbex, 75 NPK, Symspray	563	90	200	6.3	2.2
-- 75 NPK, Symbooster	586	85	196	6.9	2.3
Lime					
-- 75 N (NH_4NO_3)	558	87	206	6.4	2.4
Symbex 75 N (NH_4NO_3)	418	89	168	4.8	1.9
-- 75 NPK	486	86	189	5.7	2.2
Symbex, 75 NPK	556	87	184	6.4	2.1
-- 100 NPK	556	84	184	6.6	2.2
Symbex, 100 NPK	538	83	178	6.5	2.1
-- 100 NPK, Symcoat	731	97	290	7.5	3.0
Symbex, 75 NPK, Symspray	537	89	194	6.0	2.2
-- 75 NPK, Symbooster	520	83	189	6.3	2.3
Waller Duncan L.S.D. (0.05)	86	N.S.	50	1.2	0.5

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

Table 12. Effect of Symbex System products on number of Katahdin tubers, hills, and stems per plot and number of tubers and stems per hill in 1981.

Treatments[1]	Tubers per plot	Hills per plot	Stems per plot	Tubers per plot	Stems per plot
Fall					
Check - no treatment	241	91	224	2.6	2.5
-- 75 N (NH_4NO_3)	334	96	234	3.5	2.5
Symbex, 75 N (NH_4NO_3)	340	96	244	3.6	2.6
Symbex, 75 N (NH_4NO_3), Lime	354	91	233	3.9	2.6
-- 75 NPK	412	93	240	4.4	2.6
Symbex, 75 NPK	388	90	222	4.3	2.5
Symbex, 75 NPK, Lime	355	93	236	3.8	2.5
Symbex, 75 NPK, Lime[2]	441	99	261	4.5	2.6
Spring					
Symbex, 75 NPK	413	97	224	4.3	2.5
Symbex, 75 NPK, Lime	404	91	241	4.5	2.5
Waller Duncan L.S.D. (0.05)	46	6	28	0.5	N.S.

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

[2]Symcoat treated seed.

Table 13. Effect of Symbex System products on percent defects, number of hollow heart tubers, and specific gravity of the Katahdin potato variety in 1979.

Treatments[1]	% Sun-burn	% Mis-shapen	% Growth cracks	Hollow heart[2]	Specific gravity
No Lime					
Symbex only	1.3	18.2	2.8	1	1.076
Symbex, 30 N (urea)	4.1	14.0	1.4	8	1.081
Symbex, 60 N (urea)	5.6	12.4	2.2	12	1.078
-- 75 NPK	1.9	12.1	0.5	6	1.075
Symbex, 75 NPK	4.6	9.7	0.0	5	1.078
-- 150 NPK	6.8	13.2	1.0	7	1.065
Symbex, 150 NPK	6.8	18.4	3.7	12	1.067
Symbex, 150 NPK, Symcoat	3.5	13.1	1.5	4	1.069
Lime					
Symbex only	3.5	12.2	1.6	25	1.078
Symbex, 30 N (urea)	4.2	13.5	0.4	15	1.080
Symbex, 60 N (urea)	5.6	22.2	1.5	16	1.076
Symbex, 30 N (NH_4NO_3)	1.7	14.5	2.2	15	1.078
Symbex, 60 N (NH_4NO_3)	3.2	13.4	0.6	7	1.078
-- 75 NPK	6.1	15.7	1.0	4	1.074
Symbex, 75 NPK	4.2	14.2	0.4	3	1.074
Symbex, 75 NPK, Symcoat	5.0	11.6	0.3	7	1.076
-- 150 NPK	4.9	14.0	1.4	5	1.066
Symbex, 150 NPK	5.1	14.0	1.2	1	1.066
Symbex, 150 NPK, Symcoat	6.9	12.6	0.5	2	1.066
-- 150 NPK, Symcoat	3.7	11.6	0.2	6	1.066
Waller Duncan L.S.D. (0.05)					0.004

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

[2]Number found per 40 large tubers cut and examined.

Table 14. Effect of Symbex System products on percent defects, number of hollow heart tubers, and specific gravity of the Katahdin potato variety in 1980.

Treatments[1]	% Sunburn	% Misshapen	% Growth cracks	Hollow heart[2]	Specific gravity
No Lime					
Check - no treatment	0.6	0.7	0.0	4	1.094
-- 75 N (NH_4NO_3)	3.3	0.0	0.0	0	1.090
Symbex, 75 N (NH_4NO_3)	2.7	0.0	0.0	0	1.087
-- 75 NPK	1.6	0.0	0.0	0	1.091
Symbex, 75 NPK	2.3	0.2	0.2	1	1.092
-- 100 NPK	4.1	0.6	0.0	2	1.087
Symbex, 100 NPK	3.2	1.2	0.3	1	1.090
-- 100 NPK, Symcoat	6.1	10.0	0.3	0	1.087
-- 75 NPK, Symspray	0.9	0.2	0.0	2	1.089
Symbex, 75 NPK, Symspray	1.4	0.0	0.1	0	1.090
-- 75 NPK, Symbooster	2.3	0.4	0.0	0	1.090
Lime					
-- 75 N (NH_4NO_3)	3.4	0.0	0.0	0	1.089
Symbex, 75 N (NH_4NO_3)	3.2	0.6	0.0	0	1.093
-- 75 NPK	3.2	0.3	0.3	1	1.091
Symbex, 75 NPK	2.4	0.0	0.1	0	1.090
-- 100 NPK	5.5	0.0	1.4	4	1.087
Symbex, 100 NPK	1.0	1.1	0.5	2	1.091
-- 100 NPK, Symcoat	6.4	6.5	0.2	0	1.090
Symbex, 75 NPK, Symspray	4.0	1.2	0.3	1	1.090
-- 75 NPK, Symbooster	2.8	0.0	0.0	1	1.090
Waller Duncan L.S.D. (0.05)					0.009

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

[2]Number of tubers per 40 large tubers cut and examined.

Table 15. Effect of Symbex System products on percent defects and specific gravity of the Katahdin potato variety in 1981.

Treatments[1]	% Sunburn	% Misshapen	% Growth cracks	Specific gravity
Fall				
Check - no treatment	0.5	0.8	0.0	1.095
-- 75 N (NH_4NO_3)	3.3	3.7	1.0	1.092
Symbex, 75 N (NH_4NO_3)	5.6	5.1	0.1	1.092
Symbex, 75 N (NH_4NO_3), Lime	7.3	4.8	0.0	1.091
-- 75 NPK	2.7	6.0	0.2	1.091
Symbex, 75 NPK	3.9	4.0	0.5	1.088
Symbex, 75 NPK, Lime	9.6	2.4	0.0	1.087
Symbex, 75 NPK, Lime[2]	4.9	3.8	0.0	1.089
Spring				
Symbex, 75 NPK	6.6	4.3	0.0	1.089
Symbex, 75 NPK, Lime	3.5	5.4	0.0	1.088
Waller Duncan L.S.D. (0.05)				0.002

[1]One gallon of Symbex and pounds of N, P, and K fertilizer per acre.

[2]Symcoat treated seed.

and in 1980 and 1981 between 5.2 - 5.3. Lime applications in all years raised the soil pH approximately 0.4 units to 5.5 - 5.7. Soil calcium and magnesium were increased by lime applications in 1979 and 1981. In 1980, only magnesium was increased by lime. Lime applications decreased aluminum in 1979 and decreased manganese in 1981.

Potassium and phosphorus, which might have been expected to increase from rapid organic matter decomposition, remained unaffected by lime, fertilizer, or Symbex System products.

Acid-Tolerant Product Trial

Emergence rates were unaffected by either Symbooster or Symbex in the formulation trial (Table 16). While the check plots produced the highest numerical yield, there was no statistical difference among treatments (Table 17). This was also the case for usable yield or yield between 1-7/8 and 4 inches.

Breakdown of the total yield into six size categories does not indicate major differences among treatments when analyzed by the Waller Duncan L.S.D. (Table 18). Partitioning of the treatments, comparing Symbex versus Symbooster, revealed an effect on size distribution between the 1-7/8 to 2¼, 2¼ to 2½, and 3¼ to 4-inch size categories. Significant F-tests for these three size classes indicated that tubers are larger on the average in the Symbooster treated plots, regardless of the formulations used. Similar partitioning analysis of the acid-tolerant versus regular formulations of both products resulted in non-significant F-tests.

Yield of misshapen tubers was significantly reduced by both formulations of Symbex and Symbooster (Table 19). The high amount of sunburned tubers in the acid-tolerant Symbex treatment was significant only when compared to the acid-tolerant Symbooster treatment.

DISCUSSION

Three years of field trials using the soil inoculant, Symbex, as an aid in the production of potatoes indicate that the product is

Table 16. Symbex and Symbooster formulation trial emergence rates and percent final stand.

Treatments[1]	Number of Hills per Plot					Percent stand
	6-19	6-22	6-25	6-29	7-2	
Check	2	28	68	86	93	88
Symbex[2]	2	26	64	79	88	83
Symbex[3]	2	25	68	86	89	84
Symbooster[2]	2	24	61	81	88	83
Symbooster[3]	2	26	66	83	89	84
Waller Duncan L.S.D. (0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	--

[1]One gallon of Symbex or Symbooster per acre.

[2]Regular formulation.

[3]Acid-tolerant formulation.

Table 17. Effect of Symbex and Symbooster formulations on yield, usable yield, percent defects, and yield between 1-7/8 and 4 inches of the Katahdin potato variety.

Treatments[1]	Yield above 1½ inches Cwt./A.	Usable yield above 1½ inches Cwt./A.	Percent defects	Yield 1-7/8 to 4 inches Cwt./A.	Yield 2½ - 4 inches Cwt./A.
Check	329	294	10.4	326	267
Symbex[2]	298	276	7.8	295	236
Symbex[3]	300	265	11.9	297	240
Symbooster[2]	303	280	7.7	301	265
Symbooster[3]	316	304	3.9	310	263
Waller Duncan L.S.D.(0.05)	N.S.	N.S.	--	N.S.	N.S.

[1]One gallon of Symbex or Symbooster per acre.

[2]Regular formulation.

[3]Acid-tolerant formulation.

Table 18. Yield distribution for Katahdin potatoes into six grade size classes as affected by Symbex and Symbooster formulations.

Treatments[1]	Cwt./Acre					
	1½ to 1-7/8 inches	1-7/8 to 2¼ inches	2¼ to 2½ inches	2½ to 3¼ inches	3¼ to 4 inches	Over 4 inches
Check	3.0	13.2	45.0	180.9	86.5	0.0
Symbex[2]	3.4	19.3	40.1	162.4	73.2	0.0
Symbex[3]	3.2	18.1	39.4	162.1	77.4	0.0
Symbooster[2]	2.3	10.3	25.5	150.0	115.1	0.0
Symbooster[3]	4.3	17.6	29.2	147.9	115.4	1.9
Waller Duncan L.S.D. (0.05)	1.9	9.0	13.4	N.S.	N.S.	N.S.
Symbex[4]	3.2	18.7	39.8	162.3	75.3	0.0
Symbooster[4]	3.3	14.0	27.4	149.0	115.2	1.0
F-test (* = 0.1, ** = 0.05, *** = 0.01)	N.S.	*	***	N.S.	**	N.S.

[1]One gallon of Symbex or Symbooster per acre.

[2]Regular formulation.

[3]Acid-tolerant formulation.

[4]Treatment data of each formulation combined for F-test analysis.

Table 19. Effect of Symbex and Symbooster formulations on defects and specific gravity of the Katahdin potato.

Treatments[1]	Cwt./Acre			Specific gravity
	Sunburn	Misshapen	Growth cracks	
Check	17.1	16.7	1.1	1.071
Symbex[2]	15.5	6.5	0.0	1.071
Symbex[3]	28.3	6.7	0.0	1.076
Symbooster[2]	19.1	3.6	0.5	1.076
Symbooster[3]	11.4	0.7	0.0	1.072
Waller Duncan L.S.D. (0.05)	16.1	8.1	N.S.	N.S.

[1]One gallon of Symbex or Symbooster per acre.

[2]Regular formulation.

[3]Acid-tolerant formulation.

of little benefit in northern Maine soils. Symbex did not improve yields of quality in any season. Soil sampling indicated that Symbex did not decrease the percent organic matter or increase available nutrients when compared to plots not treated with Symbex.

Artificial inoculations must encounter a favorable soil environment in order for bacteria to successfully establish a population. Soil temperature, soil acidity, and soil moisture are important considerations.

Data collected on soil temperature in 1980 and 1981 at Aroostook Farm by Dr. Stewart Goltz (7) indicate that soil temperatures were below 50F at the time of spring applications of Symbex. Soil temperatures less than 50F may inhibit the microorganisms' growth, according to the product label.

Two fall applications in 1980 were made in preparation for the 1981 trial. At the time, August 26, the soil temperatures were near 65F at two- and four-inch depths. The temperature remained above 50F at both depths until October 5, 1980, a time span of 40 days. Results in 1981 did not reflect this favorable soil condition, since yields were not increased by fall-applied Symbex.

Soil pH is also suspected as a possible cause of the failure of Symbex in these experiments. While the product label requires a pH of at least 6.0 for optimum growth of the inoculum, the pH of unlimed plots averaged between 4.9 - 5.3. Lime applications were only able to raise the pH to between 5.5 - 5.7. In 1979, more than two tons per acre were spread on the lime plots. It is doubtful that applications at this rate or higher, as may be required, would be economically feasible for the purpose of establishing inoculum.

While soil moisture was not determined, it is still of interest, since little rain fell early in 1979 and 1980. Between June 1 and June 21, 1979, there were only 1.64 inches of precipitation and soil conditions were dry. It was more serious in 1980 when there were only 0.52 inches of precipitation between May 17 and June 18.

Soil was sufficiently moist in May and June of 1981, but was considered dry in July.

Symcoat seedpiece treatments, while not increasing yields, can affect the plant population, stolon number (unpublished data), and tubers per hill, and thus the size distribution of the harvested crop. The ability to change the amount of potatoes produced in any given size class may be beneficial, especially to seed growers. Field studies to determine optimum Symcoat rates should be conducted before recommendations can be made.

While the inclusion of Symspray and Symbooster in the 1980 yield trial did not prove beneficial, a point must be made about the Symbooster application. Due to an oversight, the Symbooster application was not made at the proper time. The product should have been applied before planting, instead of in July and the results should be judged accordingly.

The comparison of the two Symbooster applications with the Symbex applications in the formulations trial in 1981 indicates that Symbooster may be of some benefit to farmers. The increase in yield in the more marketable size class, 3¼ to 4 inches, may be a desirable effect for tablestock growers. The theory behind Symbooster, which is aiding the development of native soil organisms tolerant of Aroostook soil conditions, should be further examined. Another year or two of yield trials should be conducted exclusively with Symbooster.

SUMMARY AND CONCLUSION

1. Symbex was not effective for improving quality or yield of Katahdin potatoes in 1979, 1980, and 1981.

2. Symbex did not alter the percentage of organic matter or availability of plant nutrients in the soil.

3. The addition of up to 4400 lbs./acre of lime did not increase the soil pH to within the pH 6.0, the level considered optimum for the development of the Symbex inoculum.

4. A more acid-tolerant Symbex formulation was also not effective when tested in 1981 on Katahdin potatoes grown in soil with pH 5.4.

5. Both formulations of Symbooster tested in 1981 increased the average size of harvested tubers and decreased the amount of misshapen tubers produced.

6. Seedpiece treatments with Symcoat increased the number of tubers produced with a corresponding decrease in average tuber size.

7. The high application rate of Symcoat in 1980 produced lower yields than plots with similar fertilizer rates and non-treated seedpieces.

8. Symspray was not tested extensively and did not affect Katahdin tuber yields in 1980.

In conclusion, it appears that Symbex soil inoculant is not effective in northern Maine soils, perhaps due to an unfavorable soil environment. Symbooster soil applications in 1981 produced better type (shape) tubers with a larger average size than check plots. This product probably should be tested further on varieties such as the Russet Burbank which may be more responsive to Symbooster and its effect on tuber type. Since the application rate of Symcoat to seedpieces will vary the number and size of harvested tubers and excessive application rates will lower yields, rate studies should be considered. First, it should be determined if there is grower interest in this type of production tool. The ultimate applicability of such a product might be on early season varieties which naturally produce few tubers per hill.

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