THE EFFECTIVENESS OF FUNGICIDE COMBINATIONS FOR CONTROLLING DAMPING-OFF AND SEED DECAY IN PEAS AND BEANS

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INTRODUCTION

Several factors may be responsible for the failure of seeds to germinate or the seedlings to emerge from the soil. Some of the most common causes of reduction in stands can generally be attributed to seed decay, seedling rot, and root rot caused by soil inhabiting organisms, including both bacteria and fungi, as well as to the invasion of the germinating seeds by insects (3, 14, 29).

Species of Pythium, Rhizoctonia, Fusarium, Phytophthora, Aphanomyces, and Botrytis (7, 8, 21, 22) are among the most common fungi capable of causing seed decay and damping-off. Generally, these organisms live as saprophytes on the decaying organic matter in the soil and become parasitic by attacking the seed or the seedling as soon as it starts to germinate (15). These fungi differ in their pathogenecity, distribution and concentration in the soil, and in their growth requirements. Some species are more pathogenic than others and some crops are more susceptible than others.

The soil environment in which the seed is planted influences the type and population of the soil organisms capable of causing seed decay and seedling rot. Among the most important environmental factors are soil temperature and soil moisture (15). With other factors being constant, the severity of the infection at different temperatures is determined, to a considerable degree, by the relative growth rates of the host and the pathogen (22). As a consequence, when seeds of a high-

TEMPERATURE CROP, SUCH AS BEANS, ARE PLANTED UNDER LOW SOIL TEMPERATURE CONDITIONS, ANY DELAY IN GERMINATION USUALLY RESULTS IN INCREASED SEED DECAY BECAUSE THE SEED-DECAYING ORGANISMS DEVELOP FASTER THAN THE GERMINATION SEED. WITH THE SAME PATHOGEN A LOW TEMPERATURE CROP, SUCH AS PEAS, WILL HAVE LESS INFECTION AT LOW THAN AT MODERATE OR HIGH SOIL TEMPERATURES (3, 15, 22).

AN EXCESS OF SOIL MOISTURE IS ALSO AN IMPORTANT FACTOR BECAUSE IT FAVORS THE DEVELOPMENT OF MANY PATHOGENIC ORGANISMS, PARTICULARLY PYTHIUM SPP., WHICH ARE AQUATIC IN HABIT (3, 14).

TWO TYPES OF DAMPING-OFF OCCUR WHICH CAN BE DIFFERENTIATED ON THE BASIS OF THE SYMPTOMS EXHIBITED BY THE HOST AND THE TIME OF ATTACK BY THE PATHOGEN. IN THE PREEMERGENCE TYPE OF DAMPING-OFF, THE GERMINATING SEED OR SEEDLING MAY BE COMPLETELY DESTROYED, OR ONLY A PORTION OF THE SEED MAY BE INVADED AND THE SEEDLING EMERGES GENERALLY IN A WEAKENED CONDITION. IN POSTEMERGENCE DAMPING-OFF A SIMILAR ATTACK OCCURS AT OR BELOW THE GROUND LEVEL AFTER THE SEEDLING HAS EMERGED (15, 22).

SEED DECAY AND THE PREEMERGENCE TYPE OF DAMPING-OFF CAN BE CONTROLLED SUCESSFULLY BY COATING THE SEED WITH FUNGICIDAL CHEMICALS. THE VALUE OF SUCH TREATMENTS HAS BEEN DEMONSTRATED BY SEVERAL INVESTIGATORS (1, 8, 11, 16, 19, 21), WHO HAVE SHOWN THAT SEED TREATMENT WILL RESULT IN THE PRODUCTION OF MORE VIGOROUS PLANTS, INCREASED STANDS, AND GENERALLY A SUBSTANTIAL INCREASE IN YIELD. TODAY SEED TREATMENT HAS BECOME A STANDARD PRACTICE IN AGRICULTURE AND SINCE NEW CHEMICAL COMPOUNDS ARE DEVELOPED EVERY YEAR, STUDIES ON THEIR EFFECTIVENESS ARE NECESSARY (2).

OBJECTIVES

THE PRESENT INVESTIGATIONS WERE CONDUCTED:

1. TO DETERMINE WHETHER THE USE OF CHEMICAL FUNGICIDES IN COMBINATION WOULD INCREASE THEIR EFFECTIVENESS OVER THE USE OF EITHER CHEMICAL ALONE FOR CONTROLLING DAMPING-OFF IN PEAS AND BEANS. SPECIFIC ATTENTION WAS GIVEN TO THE COMBINATION OF A MERCURIC WITH A NON-MERCURIC TYPE OF FUNGICIDE.

2. TO ASCERTAIN WHETHER THESE CHEMICALS WERE MORE SUITABLE AGAINST ORGANISMS OPERATING AT LOW THAN AT HIGH SOIL TEMPERATURES AND VICE VERSA.

3. TO DETERMINE THE VARIOUS TYPES OF SOIL INHIBITING PATHOGENIC ORGANISMS ACTIVE UNDER LOW AND HIGH SOIL TEMPERATURE CONDITIONS.

4. TO STUDY THE EFFECTIVENESS OF THE VARIOUS CHEMICALS USED ALONE FOR CONTROLLING SEED DECAY AND DAMPING-OFF.

5. TO NOTE THE RELATIVE TOXICITY, IF ANY, OF FUNGICIDES USED ALONE AND IN COMBINATION.

THE INVESTIGATIONS INCLUDE SEVERAL SEED TREATMENT EXPERIMENTS ON ALDERMAN PEAS AND ROUND POD KIDNEY WAX BEANS CARRIED OUT UNDER GREENHOUSE CONDITIONS AT MICHIGAN STATE COLLEGE DURING THE FALL OF 1953 AND WINTER OF 1954.

REVIEW OF LITERATURE

THE TREATMENT OF SEED WITH CHEMICAL COMPOUNDS TO PREVENT DAMPING-OFF BEGAN AS EARLY AS THE SEVENTEENTH CENTURY (38). IT WAS NOT UNTIL THE DEVELOPMENT OF THE ORGANIC MERCURY COMPOUNDS, IN 1913, THAT THE MODERN USE OF CHEMICAL PROTECTANTS STARTED. ALTHOUGH THE CHEMICALS WERE USED PRIMARLY FOR PREVENTING SEED INFECTION, BETTER STANDS TOGETHER WITH MORE VIGOROUS PLANTS WERE ALSO OBTAINED. THESE FINDINGS FORMED THE BASIS FOR STUDY OF THREE OBJECTIVES OF FUNGICIDAL SEED TREATMENT: (1) SEED DISINFESTATION OR DESTRUCTION OF CONTAMINANT SPORES OR OTHER FORMS OF PATHOGENIC ORGANISMS PRESENT ON THE SEED SURFACE; (2) SEED DISINFECTION OR RIDDING THE SEED OF A PATHOGEN WHICH HAD BECOME ESTABLISHED WITHIN THE SEED COAT OR IN DEEPER-SEATED TISSUES; (3) SEED PROTECTION OR PROTECTING THE SEED AND THE YOUNG SEEDLINGS FROM SOIL INHABITING PATHOGENIC ORGANISMS WHICH MIGHT OTHERWISE CAUSE SEED DECAY BEFORE GERMINATION OR DAMPING-OFF BY PARASITING THE SEEDLING AT OR IMMEDIATELY FOLLOWING GERMINATION (3, 30, 38).

IN THE CASE OF SEED DISINFESTATION AND SEED DISINFECTION, THE ENVIRONMENT AT THE TIME OF THE TREATMENT CAN BE CONTROLLED, BUT IN SEED PROTECTION, SUCH SOIL FACTORS, AS TYPE, REACTION, MOISTURE, TEMPERATURE, AND FLORA, ARE BEYOND CONTROL. BECAUSE OF THIS, SEED TREATMENT WITH PROTECTANTS MAY BE HIGHLY SUCCESSFUL IN ONE INSTANCE AND MUCH LESS EFFECTIVE IN ANOTHER (38).

THE CHEMICALS USED TODAY FOR SEED TREATMENTS MAY BE GROUPED AS: (1) INORGANIC MERCURIALS (MERCURIC CHLORIDE), AND ORGANIC MERCURIALS

(CEPESAN, SEMESAN, ETC.); (2) COPPER AND ZINC INORGANIC COMPOUNDS, SUCH AS CUPROCIDE, ZINC OXIDE, ETC.; AND (3) NON-MERCURIAL ORGANIC COMPOUNDS WHICH CAN BE METALLIC OR NON-METALLIC, FOR EXAMPLE THE ORGANIC SULFURS AND QUINONES (25).

LEUKEL (25), IN HIS REVIEW OF THE LITERATURE ON THE RECENT DEVELOPMENTS IN SEED TREATMENT, GAVE A DETAILED REPORT ON STUDIES OF SYNERGISM AND ANTAGONISM BETWEEN MIXTURES OF FUNGICIDES AND HORMONES, INSECTICIDES, DILUENTS, AND OTHER FUNGICIDES.

THE ADVISABILITY OF ADDING GROWTH-PROMOTING SUBSTANCES TO CHEMICALS USED FOR SEED TREATMENT WAS STUDIED BY BAYLIS (6) WHO FOUND THAT THE PRESENCE OF A GROWTH-PROMOTING SUBSTANCE IN A MERCURIAL PREPARATION GAVE NO ADDITIONAL BENEFITS EITHER IN EMERGENCE, VIGOR OF GROWTH, OR REDUCED LIABILITY TO PHYTOCIDAL DAMAGE.

IN THE FIELD OF SEED TREATMENT THE SUBJECT OF SYNERGISM AND ANTAGONISM BETWEEN DIFFERENT FUNGICIDES AND INSECTICIDES HAS RECEIVED LITTLE ATTENTION (25). HOWEVER, RECENT STUDIES ON THE EFFECT OF MIXING INSECTICIDES WITH FUNGICIDES HAVE GIVEN PROMISING RESULTS. LEUKEL (25) IN 1946, FOUND THAT CERESAN AND SEMESAN JR. REDUCED THE INSECTICIDAL ACTION OF DDT SOMEWHAT, WHEREAS THE OTHER FUNGICIDES TESTED HAD NO APPARENT EFFECT ON IT. THE INSECTICIDAL ACTION OF MAGNESIUM OXIDE WAS APPARENTLY UNAFFECTED BY ANY OF THE FUNGICIDES. HOWE, ET AL. (15), IN 1952, DEMONSTRATED THAT RELIABLE CONTROL OF SEED CORN MAGGOT AND SEED DECAY ORGANISMS WAS OBTAINED WITH A COMBINATION INSECTICIDE-FUNGICIDE. THEY FOUND THAT IN COMBINATION WITH INSECTICIDES (ALDRIN, CHLORDANE, DIELDRIN AND LINDANE) ARASAN WAS MORE SATISFACTORY THAN SPERGON OR PHYGON AS SEED TREATMENT FOR BEANS. IN ORDER TO PREVENT INSECTICIDAL INJURY TO SEED, IT WAS NECESSARY TO REDUCE

THE DOSAGE TO A MINIMUM. THE EXACT NATURE OF THE INSECTICIDE INJURY WAS NOT WELL KNOWN.

ANDERSEN, ET AL. (A) AS RESULT OF FIELD EXPERIMENTS ON BEAN, FOUND NO SIGNIFICANT DIFFERENCE BETWEEN I & D (THIURAM PLUS LINDANE) AND SEED GUARD (CAPTAN PLUS LINDANE) AS SEED TREATMENTS FOR CONTROLLING MAGGOTS AND SEED DECAY ORGANISMS. THEY STUDIED THE EFFECTIVENESS OF LINDANE, DIELDRIN, HEPTACHLOR AND CHLORDANE, USED ALONE AND IN COMBINATION WITH SEVERAL FUNGICIDES INCLUDING CAPTAN, THIRAM AND PHYGON.

LEACH, ET AL. (24), CONDUCTED EXPERIMENTS FROM 1950 TO 1952 TO COMPARE THE EFFICACY OF VARIOUS FUNGICIDE-INSECTICIDE SEED TREATMENTS ON LARGE LIMA BEANS. THEY FOUND THAT IN SOME CASES, THE INSECTICIDE USED ALONE PRODUCED A REDUCTION IN EMERGENCE OF TREATED SEEDS BUT WHEN USED IN COMBINATION WITH A FUNGICIDE, THIS ADVERSE EFFECT WAS ELIMINATED OR GREATLY REDUCED.

BAYLIS (6), COMPARING THE EFFICACY OF RED CUPROUS OXIDE AND AN ORGANIC MERCURIAL CHEMICAL FOR PEA SEED TREATMENT, REPORTED THAT THE ADDITION OF A STICKER WAS UNDESIRABLE WITH BOTH FUNGICIDES.

DEZEEUW AND ANDERSEN (10), STUDYING THE DRY AND SLURRY METHODS OF CHEMICAL APPLICATION TO PEA SEEDS, REPORTED THAT CERESAN M APPLIED IN THE DRY FORM AT 4 OZ./100 LB. OF SEED, RESULTED IN SIGNIFICANT STAND INCREASES, WHEREAS STANDS OF SEVERAL PEA VARIETIES WERE REDUCED SIGNIFICANTLY WITH THE SAME RATE OF APPLICATION OF FUNGICIDE IN A WATER SLURRY. THE SAME WORKERS (1, 2) IN SIMILAR STUDIES, FOUND THAT EITHER THE SLURRY OR THE DRY METHOD WAS SATISFACTORY WITH OTHER MATERIALS AND THAT WATER AND METHOCEL SLURRIES (7% METHOCEL SOLUTION), WERE EQUALLY EFFECTIVE.

(A) UNPUBLISHED FIELD DATA.

CORCOS (9) STUDIED THE EFFECT OF ORGANIC MERCURY PROTECTANTS ON THREE VARIETIES OF PEAS, UNDER FIELD AND LABORATORY CONDITIONS. HE FOUND THAT CERESAN M SLURRY AT 4 OZ./100 LB. OF SEED, AFFECTED SOME PEA VARIETIES MORE ADVERSELY THAN OTHERS. STUDIES ON INJURY OF PEAS CAUSED BY OTHER ORGANIC MERCURY COMPOUNDS WERE ALSO INCLUDED IN HIS INVESTIGATION.

ALTHOUGH SEVERAL WORKERS HAVE STUDIED THE EFFECT OF FUNGICIDE COMBINATIONS WHEN APPLIED TO SEED, NO POSITIVE RESULTS HAVE BEEN OBTAINED WHICH SHOW EVIDENCE OF SYNERGISM OR ANTAGONISM (25). ARNDT, ET AL. (4) IN 1946, FOUND THAT DUPONT 1452F AND DOW-9B AT A RATE OF 3 GM./KG. OF SEED WERE EQUALLY EFFECTIVE IN CONTROLLING DAMPING-OFF OF SEVERAL KINDS OF COTTON SEED. IN A SECOND EXPERIMENT THEY OBTAINED THE SAME RESULTS, BUT THE EFFECTIVENESS OF THESE TWO CHEMICALS WAS NOT IMPROVED BY THE ADDITION OF FERMATE AND ZERLATE. THE COMBINATION OF DOW-9B AND CHLORANIL (SPERGON) WAS NOT SUPERIOR TO DOW-9B USED ALONE, EXCEPT IN THE LABORATORY TESTS. AS CITED BY LEUKEL (25), WILSIE, WORKING WITH HAMP SEED, OBSERVED THAT SPERGON PLUS NEW IMPROVED CERESAN WAS BETTER THAN SPERGON USED ALONE, PROBABLY BECAUSE OF THE ADDITIONAL ACTION OF THE LATTER, WHICH UNFORTUNATELY WAS NOT USED SEPARATELY FOR COMPARISON.

THE EFFECT OF CHEMICALS ON TREATED SEED MAINTAINED IN STORAGE FOR CONSIDERABLE PERIODS HAVE ALSO BEEN INVESTIGATED. LEUKEL (25) REPORTED THAT IN SOME CASES THERE WAS NO INJURY TO GERMINATION AFTER STORAGE, BUT IN OTHERS REDUCED GERMINATION OCCURRED. THE AMOUNT OF INJURY DEPENDED UPON THE MOISTURE CONTENT OF THE SEED, RATE OF FUNGICIDE APPLICATION, LENGTH AND CONDITION OF STORAGE, KIND OF SEED, ETC.

MCCALLAN (27) FOUND THAT SEVERAL VEGETABLE SEEDS INCLUDING PEAS

AND BEANS TREATED WITH CHROMATE AND ORGANIC COMPOUNDS DID NOT LOSE THEIR VIABILITY IN STORAGE AND THAT THERE WAS NO REDUCTION IN THE EFFECTIVENESS OF THE CHEMICALS TESTED. BAYLIS (5) REPORTED THAT THERE WAS NO EVIDENCE OF DIMINISHED GERMINATION IN TREATED VEGETABLE SEEDS STORED DRY FOR TEN MONTHS. WALLEN AND SKOLKO (39) NOTICED AN INCREASE IN EMERGENCE WHEN VEGETABLE SEED, HELD IN STORAGE FOR SEVERAL YEARS, WAS TREATED WITH VARIOUS SEED PROTECTANTS.

MUCH HAS BEEN WRITTEN ELSEWHERE REGARDING THE VALUE OF SEED TREATMENT AND THE RELATIVE MERITS OF DIFFERENT SEED PROTECTANTS. A REVIEW OF THIS LITERATURE SHOWS THAT, AS A RULE, CONSIDERABLE VARIATION IN THE RESPONSE OF INDIVIDUAL CROPS MAY BE EXPECTED, AS WELL AS IN THE EFFECTIVENESS OF THE CHEMICALS TESTED (28). COHN AND DEZEEUW (8), AS A RESULT OF THEIR EXPERIMENTS ON SNAP BEAN SEED TREATMENT, NOTED A VARIETAL DIFFERENCE IN REACTION TO [illegible] AND AN INTERACTION OF VARIETIES, CHEMICALS, AND ENVIRONMENTAL CONDITIONS. WALKER (37) AND ANDERSEN AND DEZEEUW (3), STUDYING THE EFFECTIVENESS OF VARIOUS SEED PROTECTANTS TO CONTROL DAMPING-OFF IN PEAS, NOTED THAT THE BENEFITS FROM SEED TREATMENT VARY WITH THE SEASON AND LOCATION. KERNKAMP (20) NOTICED THAT WITH POOR SEED OR UNFAVORABLE ENVIRONMENT, RESPONSE TO SEED TREATMENT WAS MARKED; BUT WITH GOOD SEED AND FAVORABLE ENVIRONMENTAL CONDITIONS, THERE WAS NO RESPONSE. GERDEMANN (12) FOUND THAT SOME TREATMENTS WHICH APPEARED HARMLESS IN WET SOIL, REDUCED EMERGENCE OR CAUSED INJURY IN DRY SOIL. HE OBSERVED ALSO (13) THAT SEED TREATMENT OF SMALL SEEDED LEGUMES WAS EFFECTIVE WHEN THE TREATED SEED WAS PLANTED IN COLD WET SOIL. JACKS (16) REPORTED THAT TREATMENT OF VEGETABLE SEEDS FOR FIELD TRIALS WAS GENERALLY MORE BENEFICIAL WHEN THE SEED WAS PLANTED IN COOL AND MOIST SOIL. HE OBTAINED IMPROVED

EMERGENCE IN ALL BUT THE DRIEST SOIL. PORTER (31), WORKING IN BRAZIL, FOUND THAT DIFFERENT PEA VARIETIES REPRESENTING SMOOTH AND WRINKLED SEED TYPES, WERE BENEFITED BY SEED TREATMENT, ALTHOUGH THERE WAS EVIDENCE THAT SOME VARIETIES RESPONDED MORE THAN OTHERS.

MACHACEK AND BROWN (28), IN FIELD TRIALS WITH VARIOUS SEED DISINFECTANTS SHOWED THAT SEED DISINFECTION SOMETIMES INCREASED BOTH GERMINATION AND YIELD OF RADIUM PEAS, AND SOMETIMES DID NOT; IN SOME INSTANCES, IMPROVEMENT IN GERMINATION WAS NOT FOLLOWED BY AN IMPROVEMENT IN YIELD. COHN AND DEZEEUW (8) FOUND THAT WAX BEAN VARIETIES WERE BENEFITED MORE BY SEED TREATMENT THAN WERE GREEN BEANS. WALLEN (40) REPORTED THAT, IN GENERAL, MOST OF THE CRUCIFERS RESPONDED TO SEED TREATMENT.

THE RESULTS OBTAINED BY SEVERAL WORKERS ON VEGETABLE SEED TREATMENT EXPERIMENTS ARE NUMEROUS AND VARIED. NO ATTEMPT IS MADE TO PRESENT A COMPLETE REVIEW OF THE LITERATURE ON THE SUBJECT. ATTENTION HAS BEEN GIVEN TO THE MOST IMPORTANT PAPERS DEALING WITH THE EFFECTIVENESS OF SEED PROTECTANTS AS APPLIED TO PEAS AND BEANS FOR CONTROLLING SEED DECAY AND DAMPING-OFF.

IN 1931 JONES (19) NOTICED TWO DISTINCT PHASES OF SEED TREATMENT TO BE CONSIDERED: (1) THE VALUE OF SEED TREATMENT IN THE CONTROL OF SEED-BORNE DISEASES, AND (2) THE PROTECTECTION OF SEED FROM DECAY CAUSED BY SOIL-BORNE ORGANISMS PRIOR TO THE GERMINATION OF THE SEED AND THE ESTABLISHMENT OF THE YOUNG SEEDLING. WORKING WITH PEA SEED TREATMENTS, HE FOUND THAT ORGANIC MERCURY DUSTS CONTAINING A LEAST 12% OF MERCURY PHENOLATE WERE MOST EFFECTIVE IN INCREASING THE STANDS. AN INCREASE IN GERMINATION RESULTED FROM TREATING THE SEED WITH SEMESAN UNDER VARIOUS SOIL MOISTURE AND SOIL TEMPERATURE CONDITIONS.

LEACH (21) IN 1940 REPORTED THAT DAMPING-OFF OF SOME VEGETABLE CROPS CAUSED BY PYTHIUM ULTIMUM WAS SATISFACTORILY CONTROLLED BY SEED TREATMENT WITH RED OXIDE OF COPPER, BUT ORGANIC MERCURY COMPOUNDS WERE MORE EFFECTIVE WHEN INFECTION WAS DUE TO RHIZOCTONIA SOLANI.

LEACH AND SMITH (23), WORKING WITH GARDEN PEAS, IN 1945, SHOWED THAT SEMESAN AND YELLOW CUPROCIDE APPEARED TO PROVIDE A BETTER PROTECTION AGAINST INFECTION CAUSED BY PYTHIUM ULTIMUM IN ARTIFICALLY INFESTED SOIL THAN ARASAN, NEW IMPROVED CERESAN, OR SPERGON, ALTHOUGH THE DIFFERENCES WERE NOT GREAT. IN FIELD TRIALS WHERE INFESTATIONS WERE OF MODERATE INTENSITY, ALL THE CHEMICALS PROVIDED ADEQUATE PROTECTION, BUT SPERGON AND SEMESAN PRODUCED BETTER RESULTS IN SOME TESTS.

IN NATION-WIDE TESTS SPONSORED BY THE SEED TREATMENT COMMITTEE OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY IN 1948 (34), IDAHO REPORTED PHYGON, ARASAN AND SPERGON AS THE BEST SEED PROTECTANTS TO CONTROL SEED DECAY AND DAMPING-OFF IN THOMAS LAXTON PEAS.

COHN AND DEZEEUW (8) IN 1949, TESTED TEN VARIETIES OF SNAP BEAN WITH FIVE DIFFERENT SEED PROTECTANTS. THEY FOUND THAT SPERGON AT 4 OZ./100 LB. OF SEED PRODUCED A SIGNIFICANT INCREASE IN GEMINATION OF MOST OF THE VARIETIES IN 30- PERCENT OF THE TESTS, L-224 AND ARASAN BEING LESS EFFECTIVE. DOW F800 AND L-640, BOTH APPLIED AT 4 OZ./100 LB. OF SEED, WERE TOXIC TO CERTAIN VARIETIES, BUT L-640, WHEN APPLIED AT 2 OZ./100 LB. OF SEED, CAUSED AN INCREASE IN GERMINATION.

IN A COMPARATIVE STUDY ON THE EFFECTIVENESS OF SEPARATE AND COMBINED SEED AND SOIL TREATMENT, MCKEEN (29) OBSERVED THAT ARASAN APPLIED TO THE SOIL PRIOR TO PLANTING, WAS HIGHLY EFFECTIVE IN CONTROLLING PREEMERGENCE AND POSTEMERGENCE DAMPING-OFF IN CERTAIN VEGTABLES. SOIL TREATMENT WITH ARASAN WAS MARKEDLY SUPERIOR TO SEED

TREATMENT. A COMBINED SEED AND SOIL TREATMENT WAS USUALLY MORE EFFECTIVE THAN EITHER TREATMENT ALONE.

IN 1949, ARASAN AND SPERGON WERE REPORTED IN MARYLAND AS BEING THE BEST FOR PRIDE PEAS, AND IN A COOPERATIVE EXPERIMENT IN FOUR STATES, C & C L-640 WAS FOUND THE BEST AND C & C L-640, SECOND BEST FOR CONTROLLING DAMPING-OFF IN PEAS. WISCONSIN REPORTED A NEW PROTECTANT (KF467) AS THE BEST (35).

BOOSALIS (7) SHOWED THAT SOYBEAN DAMPING-OFF CAUSED BY RHIZOCTONIA SOLANI WAS CONSIDERABLY REDUCED BY TREATING THE SEED WITH SPERGON AND CERESAN M. MCCALLAN (27) TESTED SEVERAL CHROMATE AND ORGANIC COMPOUNDS AS POSSIBLE SEED PROTECTANTS IN THE GREENHOUSE ON SEVERAL VEGETABLE SEEDS INCLUDING PEAS AND BEANS. HE FOUND THAT COPPER-ZINC-CHROMATE RANKED FIRST ON PEAS AND THAT FAIR RESULTS WERE OBTAINED ON THE OTHER VEGETABLE CROPS EXCEPT LIMA BEANS TO WHICH IT WAS PROBABLY INJURIOUS.

MCNEW AND MCCALLAN (30) NOTICED THAT CHLORANIL (SPERGON), ONE OF THE QUINONE ORGANIC COMPOUNDS, WAS FOUND TO BE USEFUL AS A PROTECTANT FOR MANY TYPES OF SEED, INCLUDING PEAS, LIMA BEANS, CORN, AND OTHERS. THEY NOTED THAT THERE WERE SOME LIMITATIONS IN ITS USE, NAMELY SOIL TEXTURE AND ALKALINITY, WHICH APPEARED TO INFLUENCE THE EFFECTIVENESS OF SPERGON AS A GOOD SEED PROTECTANT. THE SAME AUTHORS (30) IN THEIR DISCUSSION ON SEED TREATMENT EXPERIMENTS, NOTICED THAT OF THE FIFTEEN STATES REPORTING EXPERIMENTS ON PEA SEED TREATMENT UP TO 1950, TWELVE RECOMMENDED SPERGON AS THE MOST EFFECTIVE SEED PROTECTANT AGAINST PEA SEED DECAY CAUSED BY PYTHIUM SPP., AND FOURTEEN REPORTED IT TO BE ACCEPTABLE AS A SEED

TREATMENT. ARASAN WAS NEXT TO SPERGON IN NINE OF THE FIFTEEN STATES. FOR LIMA BEAN SEED TREATMENT, SIX STATES RECOMMENDED SPERGON AS AN ACCEPTABLE SEED TREATMENT, AND TWELVE STATES RECOMMENDED SPERGON FOR SNAP BEANS.

JACKS (16) TESTED SEVEN CHEMICALS IN GREENHOUSE AND FIELD TRIALS ON SEVERAL VEGETABLE SEEDS, INCLUDING PEAS AND FRENCH BEANS. HE FOUND THAT THIRAM, CHLORANIL, AND 26L (1-P-SULFAMYLPHENYL-3-5-DIMETHYL-4-NITROSOPYRAZOLE), WHERE THE MOST EFFECTIVE SEED PROTECTANTS.

HAGBERG (14), REPORTING THE RESULTS ON HIS EXPERIMENTS WITH PEA SEED PROTECTANTS FOUND THAT ARASAN, KF467, PHYGON, AND SPERGON WERE SIGNIFICANTLY MORE EFFECTIVE THAN ARASAN SF-X, DOW 9B AND PHYGON XL.

REPORTS ON BEAN SEED TREATMENTS IN COLORADO MENTIONED THAT DITHANE Z-78, ORTHOCIDE 406, CRAG #531, CERESAN M, PHYGON XL, ARASAN AND DOW 9B WERE THE MOST EFFECTIVE SEED PROTECTANTS (36).

ANDERSEN AND DEZEEUW (2) REPORTED SEVERAL FUNGICIDES EFFECTIVE AS PEA SEED PROTECTANTS. OF THESE, PHYGON XL, PHYGON, AND SEMESAN WERE THE BEST. OTHERS LIKE CERESAN M, ARASAN, ARASAN SF-X, C&C L-224 AND PANOGEN WERE GOOD IN SOME SEASONS BUT NOT IN OTHERS.

THE SAME WORKERS (1) PRESENTED RESULTS BASED UPON THREE YEARS EXPERIMENTS ON SEED TREATMENT OF GARDEN AND CANNING BEANS WHICH SHOWED THAT ARASAN, C & C L-224, PHYGON XL, SEMESAN, ORTHOCIDE 406, BASIC COPPER CARBONATE, AGROX AND OTHER CHEMICALS WERE EFFECTIVE AS SEED PROTECTANTS.

ANDERSEN AND DEZEEUW, (A) REPORTED RECENTLY THE RESULTS FROM 1953 FIELD EXPERIMENTS ON ALDERMAN PEA SEED TREATMENTS WITH VARIOUS CHEMICAL PROTECTANTS. ORTHOCIDE 75 WAS THE BEST FOR PREVENTING

(A) UNPUBLISHED FIELD DATA.

DAMPING-OFF AND SEED DECAY. RANKING NEXT WERE SEMESAN, ORTHO SEED GUARD, PHYGON S. P., C & C L-640, AND ARASAN. SPERGON WAS AMONG THE LEAST EFFECTIVE CHEMICALS. THEIR RESULTS FROM THE 1953 FIELD EXPERIMENTS ON ROUND POD KIDNEY WAX BEAN SEED TREATMENT SHOWED THAT ARASAN PLUS DIELDRIN (DU PONT), MERCULINE, ORTHO SEED GUARD, FERMULINE, SEMESAN AND I & D (DU PONT) AS THE MORE EFFECTIVE SEED TREATMENT CHEMICALS FOR PREVENTING DAMPING-OFF AND SEED DECAY. SPERGON WAS AMONG THE LEAST EFFECTIVE CHEMICALS.

MATERIALS AND METHODS

Pea seed (*Pisum sativum* L.) of the variety Alderman and bean seed (*Phaseolus vulgaris* L.), variety Round Pod Kidney Wax, were selected for investigations on combination seed treatments because of their high susceptibility to damping-off and because of their ease of handling and treating.

The name, active ingredients and manufacturers of the mercuric and non-mercuric fungicides used in the seed treatment experiments, are given in Table I. The fungicides were applied to the seed two or three days before planting at rates calculated in ounces per hundred pounds of seed. The required amount of dusts or liquids at, above, or below the rates recommended by the manufacturers, was measured accurately and applied to the seed in 125 ml. Erlenmeyer flasks. Even distribution of the dust or liquid was ensured by shaking and rotating the flask until the seeds were well coated. Dust materials were applied as dry treatments. When liquid chemicals were used alone or in combination with a dust, a few drops of a 7% Methocel solution was added.

Soil which had previously been used to grow peas and beans and which was heavily infested with damping-off organisms, was mixed with new compost and sand at a rate of one part old soil, one part new compost and one part sand. This gave a sandy loam medium which did not pack heavily when watered.

Wood flats, 14 x 21 x 3½ inches in size were used in all the experiments. The flats were large enough to plant ten rows each with fifteen seeds and the seeds were covered uniformly with one inch of soil.

EACH TREATMENT WAS REPLICATED FOUR TIMES WITH DOUBLE ROWS OF SEED FOR EACH REPLICATION IN ALL EXPERIMENTS EXCEPT FOR THE FINAL BEAN EXPERIMENT WHICH WAS REPLICATED FIVE TIMES. NO REPLICATION WAS USED IN STRICTLY PRELIMINARY TRIALS.

APPROPIATE UNTREATED CONTROLS WERE INCLUDED AND EACH EXPERIMENT WAS A RANDOMIZED EXPERIMENTAL DESIGN. IN GENERAL, THE EXPERIMENTS WERE CONDUCTED FOLLOWING THE METHODS ADOPTED FOR GREENHOUSE SEED TREATMENT EXPERIMENTS AS GIVEN BY McCALLAN (26) AND JACKS (16).

AFTER PLANTING, THE FLATS WERE PERIODICALLY WATERED IN ORDER TO PROVIDE CONVENIENT MOISTURE TO THE GERMINATING SEED, THE MOISTURE BEING MAINTAINED AT SIMILAR LEVELS THROUGHOUT ALL THE EXPERIMENTS, ACCORDING TO THE RECOMMENDATIONS OF JONES (19).

THE PLANTED FLATS WERE PLACED IN TWO DIFFERENT GREENHOUSES MAINTAINED AT TWO DIFFERENT AIR TEMPERATURES WHICH PROVIDED TWO DIFFERENT SOIL TEMPERATURES. THE LOW SOIL TEMPERATURE RANGE WAS FROM 15° TO 18°C., AND THE HIGH SOIL TEMPERATURE RANGED FROM 20° TO 24°C. THE LOW GREENHOUSE AIR TEMPERATURE RANGED FROM 16° TO 20°C, AND FROM 22° TO 26°C. FOR THE HIGH TEMPERATURE.

AS MENTIONED BY McCALLAN (26), POSTEMERGENCE DAMPING-OFF IS GENERALLY INDEPENDENT OF THE SEED TREATMENT AND THE EFFECTIVENESS OF THE CHEMICALS TESTED MAY BE ESTIMATED ON THE BASIS OF PERCENTAGE OF PLANTS EMERGED AFTER FOURTEEN DAYS. HOWEVER, DATA ON POST-EMERGENCE DAMPING-OFF, IN ADDITION TO PREEMERGENCE DAMPING-OFF, WERE RECORDED ESPECIALLY FOR COMPARISON OF DAMPING-OFF SEVERITY AT

THE TWO SOIL TEMPERATURES USED. THESE DATA ARE GIVEN IN SEPARATE TABLES FOR THE TWO FIRST PEA AND BEAN EXPERIMENTS RESPECTIVELY.

PERCENTS OF PREEMERGENCE DAMPING-OFF WERE TAKEN TWO WEEKS AFTER PLANTING ON THE BASIS OF TOTAL NUMBER OF PLANTS EMERGED. RECORDS ON POSTEMERGENCE DAMPING-OFF WERE MADE THREE WEEKS AFTER PLANTING BY REMOVING THE PLANTS FROM THE SOIL AND COUNTING THE HEALTHY SEEDLINGS.

THE RESULTS FROM ALL THE REPLICATED EXPERIMENTS WERE STATISTICALLY ANALIZED USING THE ANALYSIS OF VARIANCE (33). THE DIFFERENCES FOR SIGNIFICANCE AT THE 5-PERCENT AND 1-PERCENT LEVELS ARE GIVEN AT THE BOTTOM OF EACH TABLE. VARIATIONS WITHIN INDIVIDUAL EXPERIMENTS ARE PRESENTED AS EACH EXPERIMENT IS DISCUSSED.

EXPERIMENTAL RESULTS

PRELIMINARY INVESTIGATIONS

TWO IDENTICAL PRELIMINARY EXPERIMENTS USING THE ALDERMAN PEA AND THE ROUND POD KIDNEY WAX BEAN WERE CARRIED OUT TO OBTAIN A TENTATIVE SELECTION OF THE MORE PROMISING MATERIALS TO BE USED IN SUBSEQUENT EXPERIMENTS EITHER ALONE OR IN COMBINATION. THE FOUR MERCURIC AND NON-MERCURIC ORGANIC CHEMICALS SELECTED ARE GIVEN IN TABLE 1. THE CHEMICALS WERE APPLIED AT A RATE OF 2 OUNCES/100 POUNDS OF SEED WHEN USED ALONE, AND AT 1 OUNCE/100 POUNDS OF SEED WHEN USED IN COMBINATION, EXCEPT FOR VANCIDE 51 WHICH WAS APPLIED AT 4 OUNCES AND 2 OUNCES/100 POUNDS OF SEED RESPECTIVELY.

THE CHEMICALS WERE TESTED IN ALL POSSIBLE COMBINATIONS UNDER BOTH LOW (16° TO 20° C.) AND HIGH (20° TO 24° C.) SOIL TEMPERATURE CONDITIONS. TEN TREATMENTS INCLUDING A CHECK, WERE PLANTED IN EACH FLAT. DATA ON PREEMERGENCE AND POSTEMERGENCE DAMPING-OFF WERE TAKEN BUT, BECAUSE THE TREATMENTS WERE NOT REPLICATED, NO STATISTICAL ANALYSIS OF THE EXPERIMENTS COULD BE MADE.

THE EXPERIMENTS, AS STATED BEFORE, SERVED AS A BASIS FOR SELECTING THE CHEMICALS WHICH APPEARED TO BE EFFECTIVE AS SEED TREATMENT MATERIALS WHEN USED ALONE AND IN COMBINATION TO CONTROL DAMPING-OFF AT TWO SOIL TEMPERATURES. IN ADDITION, AN ESTIMATION ON THE EFFECT OF TEMPERATURE ON SEED GERMINATION WAS OBTAINED, TOGETHER WITH PRELIMINARY INDICATIONS OF CHEMICAL TOXICITY.

PEA EXPERIMENTS

ON THE BASIS OF THE RESULTS OBTAINED IN THE PRELIMINARY EXPERIMENTS, AGROX, ORTHOCIDE 75, SPERGON, SEMESAN, C & C L-224, AND ARASAN SF-X,

TABLE 1. NAME, CHEMICAL COMPOSITION, AND SOURCE OF THE FUNGICIDES USED IN THE PEA AND BEAN SEED TREATMENT EXPERIMENTS.

TRADE OR CODE NAME	ACTIVE INGREDIENT	SOURCE
MERCURIC FUNGICIDES		
AGROX	PHENYL MERCURY UREA (6.7%)	CHIPMAN CHEM. CO.
C & C L-224	MERCURY-ZINC-CHROMATE	CARBIDE & CARBON CHEM. CO.
PURATIZED C-15 1212	ORGANIC MERCURY-CADMIUM COMPOUNDS	GALLOWHUR CHEM. CORP.
SEMESAN	HYDROXYMERCURI CHLOROPHENOL (30%)	E. I. DU PONT DE NEMOURS & CO. (INC.)
NON MERCURIC FUNGICIDES		
ARASAN SF-X (THIRAM)	TETRAMETHYLTHIURAM DISULPHIDE (75%)	E. I. DU PONT DE NEMOURS & CO. (INC.)
ORTHOCIDE 75 (CAPTAN)	N-TRICHLOROMETHYLTHIO TETRAHYDROPTHALIMIDE (75%)	CALIF. SPRAY CHEM. CORP.
SPERGON (WETTABLE)	TETRACHLORO-P-BENZOQUINONE (48%)	U. S. RUBBER CO.
VANCIDE 51	SODIUM SALTS OF DIMETHYL DITHIC-CARBAMIC ACID AND 2 MERCAPTOBENZOTHIAZOLE (30%)	R. T. VANDERBILT CORP.

WERE SELECTED FOR FURTHER STUDY AS TO THEIR EFFECTIVENESS WHEN USED ON PEAS AT TWO SOIL TEMPERATURES.

THE RESULTS, PRESENTED IN TABLE 2, SHOW THAT MOST OF THE CHEMICALS WERE EFFECTIVE IN CONTROLLING DAMPING-OFF OF PEAS WHEN USED ALONE, BUT ORTHOCIDE 75 WAS THE BEST. FURTHERMORE, ALL THE COMBINATIONS CONTAINING ORTHOCIDE 75 WERE EQUALLY AS EFFECTIVE AS THIS CHEMICAL ALONE AND SUPERIOR TO ALL THE OTHER TREATMENTS.

RANKING NEXT TO ORTHOCIDE 75, IN ORDER OF DECREASING EFFECTIVENESS, WERE AGROX, C & C L-224, ARASAN (SF-X), SEMESAN, AND SPERGON. ALTHOUGH SOME OF THE COMBINATIONS APPEARED TO BE SUPERIOR TO EITHER CHEMICAL ALONE, THE DIFFERENCES WERE NOT STATISTICALLY SIGNIFICANT. IT APPEARS THAT THE EFFECTIVENESS OF THE COMBINATIONS IS DIRECTLY RELATED TO THAT OF THE SAME MATERIALS USED ALONE. THIS IS ESPECIALLY EVIDENT FOR THE LESS EFFECTIVE CHEMICALS.

THERE WERE NO SIGNIFICANT DIFFERENCES BETWEEN THE FUNGICIDES USED ALONE AND IN COMBINATION, AND NO DIFFERENCES WERE FOUND REGARDING THE EFFECTIVENESS OF THE CHEMICALS AND THEIR COMBINATIONS IN CONTROLLING PREEMERGENCE DAMPING-OFF UNDER LOW AND HIGH SOIL TEMPERATURE CONDITIONS. THE HIGHER PERCENTAGE OF POSTEMERGENCE DAMPING-OFF WAS OBSERVED ON PLANTS GROWN AT THE SOIL TEMPERATURES (TABLE 3).

IN ORDER TO DETERMINE THE ORGANISMS RESPONSIBLE FOR DAMPING-OFF, SEVERAL ISOLATIONS WERE MADE FROM SEEDLINGS SHOWING DAMPING-OFF SYMPTOMS. DISEASED SEEDLINGS WERE TAKEN AT RANDOM FROM SOIL MAINTAINED UNDER LOW AND HIGH SOIL TEMPERATURE CONDITIONS. THE ISOLATES OBTAINED WERE SIMILAR TO THOSE REPORTED BY OTHER WORKERS (5, 16, 22, 23), WHO HAVE STUDIED DAMPING-OFF OF PEAS.

TABLE 2. PERCENTAGE EMERGENCE OF ALDERMAN PEA SEEDLINGS AFTER SEED TREATMENT WITH FUNGICIDES ALONE AND IN COMBINATION, AT LOW (16° -- 20° C.) AND HIGH (20° -- 24°C.) SOIL TEMPERATURES.

TREATMENT[B]	TOTAL EMERGENCE[A]	
	SOIL TEMPERATURE	
	16° -- 20°C.	20° -- 24°C.
	PERCENT	PERCENT
AGROX	75	73
AGROX PLUS ORTHOCIDE	87	81
ORTHOCIDE	83	83
AGROX PLUS SPERGON	56	53
SPERGON	15	10
SPERGON PLUS ORTHOCIDE	84	87
SEMESAN	56	56
SEMESAN PLUS ORTHOCIDE	83	91
SEMESAN PLUS SPERGON	67	63
C & C L-224	63	70
C & C L-224 PLUS ARASAN	68	61
ARASAN	61	61
ARASAN PLUS ORTHOCIDE	88	75
ARASAN PLUS SPERGON	48	62
NON-TREATED CONTROL	6	6
L. S. D.: 5-PERCENT LEVEL	13	12
1-PERCENT LEVEL	16	15

A. BASED ON THE AVERAGE OF 4 REPLICATED PLOTS OF 30 SEEDS EACH.

B. CHEMICALS USED ALONE AT 2oz./100 LB. OF SEED; CHEMICALS USED IN COMBINATION AT 1 oz./100 LB. OF SEED.

TABLE 3. PERCENTAGE OF POSTEMERGENCE DAMPING-OFF OF ALDERMAN PEA SEEDLINGS AT LOW (16° - 20°C.) AND HIGH (20° - 24°C.) SOIL TEMPERATURES AFTER TREATMENT WITH VARIOUS FUNGICIDES ALONE AND IN COMBINATION.

TREATMENT [B]	POSTEMERGENCE DAMPING-OFF [A]	
	SOIL TEMPERATURE	
	16° - 20°	20° - 24° C.
	PERCENT	PERCENT
AGROX	2	17
AGROX PLUS ORTHOCIDE	3	27
ORTHOCIDE	11	36
AGROX PLUS SPERGON	0	14
SPERGON	8	3
SPERGON PLUS ORTHOCIDE	0	30
SEMESAN	3	23
SEMESAN PLUS ORTHOCIDE	6	30
SEMESAN PLUS SPERGON	5	21
C & C L-224	9	33
C & C L-224 PLUS ARASAN	11	26
ARASAN	14	29
ARASAN PLUS ORTHOCIDE	9	30
ARASAN PLUS SPERGON	6	25
NON-TREATED CONTROL	3	3

A. BASED ON THE AVERAGE OF FOUR REPLICATED PLOTS OF 30 SEEDS EACH.
B. CHEMICALS USED ALONE AT 2 OZ./100 LB. OF SEED; CHEMICALS USED IN COMBINATION AT 1 OZ./100 LB. OF SEED.

PYTHIUM SPP. WERE THE MOST ABUNDANT ISOLATES OBTAINED FROM THE DISEASED SEEDLINGS GROWN AT LOW SOIL TEMPERATURES (16° - 20° C.). FUSARIUM SPP. WERE IN SECOND PLACE, AND RHIZOCTONIA SPP. WERE THE LEAST IN NUMBERS. WHEN THE ISOLATES WERE MADE FROM DISEASED SEEDLINGS GROWING AT THE HIGH SOIL TEMPERATURES (20° - 24° C.), FUSARIUM SPP. WERE MOST PREDOMINANT, FOLLOWED BY RHIZOCTONIA SPP. AND PYTHIUM SPP.

HAVING IN MIND THE FINDINGS OF BAYLIS (5), LEACH (20), GEBDEMANN (13), AND OTHERS, WHO DEMONSTRATED THAT PREEMERGENCE DAMPING-OFF WAS MOST SEVERE AT TEMPERATURES LESS FAVORABLE TO THE HOST THAN TO THE PATHOGEN, AND ALSO CONSIDERING THAT NO VARIATION IN THE EFFECTIVENESS OF THE CHEMICALS USED ALONE AND IN COMBINATION WAS OBSERVED AT LOW AND HIGH SOIL TEMPERATURES, A SECOND EXPERIMENT ON ALDERMAN PEAS WAS CONDUCTED. IN THIS EXPERIMENT THE SAME CHEMICALS WERE USED AS IN THE PREVIOUS EXPERIMENT BUT THE TESTS WERE MADE ONLY AT THE HIGHER SOIL TEMPERATURES (20° - 24° C.). THE AMOUNT OF CHEMICAL APPLIED WAS VARIED, IN SOME INSTANCES BELOW OR OVER THE MANUFACTURERS RECOMMENDED DOSAGE. THE RESULTS ARE PRESENTED IN TABLE 4.

ORTHOCIDE 75, AGAIN GAVE THE BEST PREEMERGENCE DAMPING-OFF CONTROL EVEN WHEN APPLIED AT THE L OUNCE RATE. RANKING NEXT IN ORDER OF DECREASING EFFECTIVENESS WERE ARASAN SF-X, AGROX, SEMESAN, C & C L-224, AND SPERGON.

SPERGON, ALTHOUGH APPLIED AT A HIGH RATE OF 4 OUNCES/100 POUNDS OF SEED, WAS COMPARATIVELY INEFFECTIVE AS A SEED TREATMENT MATERIAL. NO SIGNIFICANT DIFFERENCE WAS FOUND BETWEEN ORTHOCIDE 75 WHEN APPLIED AT 2 OUNCES AND AT 1 OUNCE/100 POUNDS OF SEED. BUT THE EFFICACY OF SPERGON WAS SIGNIFICANTLY BETTER WHEN APPLIED AT 4 OUNCES AS COMPARED WITH THE 2 OUNCE RATE.

TABLE 4. PERCENTAGE EMERGENCE OF ALDERMAN PEA SEEDLINGS AFTER SEED TREATMENT WITH FUNGICIDES, USING DIFFERENT DOSAGES AND COMBINATIONS OF CHEMICALS AT HIGH (20° - 24°C.) SOIL TEMPERATURES.

TREATMENT, OUNCES PER 100 POUNDS OF SEED	TOTAL EMERGENCE [A]
	PERCENT
AGROX, 2	78
AGROX, 1 PLUS ORTHOCIDE, 1	84
AGROX, 1 PLUS ORTHOCIDE, 0.5	80
ORTHOCIDE, 2	91
ORTHOCIDE, 1	83
AGROX, 1 PLUS SPERGON, 2	64
AGROX, 1 PLUS SPERGON, 1	66
SPERGON, 4	49
SPERGON, 2	22
SPERGON, 2 PLUS ORTHOCIDE, 0.5	87
SPERGON, 1 PLUS ORTHOCIDE, 1	82
NON-TREATED CONTROL	6
SEMESAN, 1 PLUS ORTHOCIDE, 1	87
SEMESAN, 1 PLUS ORTHOCIDE, 0.5	81
SEMESAN, 2	67
SEMESAN, 1 PLUS SPERGON, 2	68
SEMESAN, 1 PLUS SPERGON, 1	67
C & C L-224, 2	58
C & C L-224, 1 PLUS ARASAN, 1	81
ARASAN, 2	81
ARASAN, 1 PLUS ORTHOCIDE, 1	95
ARASAN, 1 PLUS ORTHOCIDE, 0.5	88
ARASAN, 1 PLUS SPERGON, 2	66
ARASAN, 1 PLUS SPERGON, 1	82
NON-TREATED CONTROL	5
L. S. D.: 5-PERCENT LEVEL	11
1-PERCENT LEVEL	12

A. BASED ON THE AVERAGE OF 4 REPLICATED PLOTS OF 30 SEEDS EACH.

As in the previous experiment, no increase in the efficacy of the chemicals was observed when used in combination. There appears to be a correlation between the effectiveness of the combinations and the efficacy of the components of the combination, that is, the greater the effectiveness of the chemicals when used alone, the greater the efficacy of their combinations.

In a third experiment, five chemicals selected from the previous test were retested as to their effectiveness in soil maintained at the higher temperature (20° - 24°C.). Lower rates of application were made in order to avoid a masking of the effect of one chemical by the other when the higher rates were used. The results are presented in Table 5. At the rates used, all the treatments with the exception of Spergon alone, when used alone and in combination, gave good preemergence damping-off control. However, the degree of control was not as good as those obtained in previous trials. Orthocide 75 was an effective seed protectant even at a rate of 0.5 ounces/100 pounds of seed. Although the dosage of Spergon was increased to 6 ounces/100 pounds of seed, there was little increase in its effectiveness as a seed protectant. As in previous experiments, no significant differences were found between the chemicals used alone and in combination.

In the final pea seed treatment experiment, a comparison was made between Arasan SF-X and Orthocide 75, used alone and in combination at different rates, as shown in Table 6. Soil temperature ranges were higher than in previous experiments. As a result of these unfavorable conditions, damping-off was more severe. All the chemicals and their combinations, although used at low rates, were effective in increasing

TABLE 5. PERCENTAGE EMERGENCE OF ALDERMAN PEA SEEDLINGS AFTER SEED TREATMENT WITH FUNGICIDES, USING DIFFERENT DOSAGES AND COMBINATIONS OF CHEMICALS AT HIGH (20° - 24°C.) SOIL TEMPERATURES.

TREATMENT, OUNCES PER 100 POUNDS OF SEED	TOTAL EMERGENCE [A]
	PERCENT
AGROX, 1	64
AGROX, 0.5 PLUS ORTHOCIDE, 0.25	50
ORTHOCIDE, 0.5	48
ORTHOCIDE, 0.25 PLUS SPERGON, 3	50
SPERGON, 6	17
AGROX, 0.5 PLUS SPERGON, 3	24
SEMESAN, 2	67
SEMESAN, 1 PLUS ORTHOCIDE, 0.25	51
SEMESAN, 1 PLUS SPERGON, 3	43
SEMESAN, 1 PLUS AGROX, 0.5	54
ARASAN, 1	37
ARASAN, 0.5 PLUS ORTHOCIDE, 0.25	52
ARASAN, 0.5 PLUS SPERGON, 3	42
ARASAN, 0.5 PLUS AGROX, 0.5	52
NON-TREATED CONTROL	4
L. S. D.: 5-PERCENT LEVEL	17
1-PERCENT LEVEL	21

A. BASED ON THE AVERAGE OF 4 REPLICATED PLOTS OF 30 SEEDS EACH.

TABLE 6. PERCENTAGE EMERGENCE OF ALDERMAN PEA SEEDLINGS AFTER TREATMENT WITH FUNGICIDES, USING DIFFERENT DOSAGES AND COMBINATIONS OF CHEMICALS AT HIGH (21° - 24° C.) SOIL TEMPERATURES.

TREATMENT OUNCES PER 100 POUNDS OF SEED	TOTAL EMERGENCE [A]
	PERCENT
ARASAN, 2	57
ARASAN, 1	43
ARASAN, 0.5	37
ORTHOCIDE, 1	52
ORTHOCIDE, 0.5	49
ARASAN, 1 PLUS ORTHOCIDE, 1	56
ARASAN, 0.5 PLUS ORTHOCIDE, 0.5	35
ARASAN, 0.5 PLUS ORTHOCIDE, 0.25	18
ARASAN, 0.25 PLUS ORTHOCIDE, 0.5	46
NON-TREATED CONTROL	1
L. S. D.: 5-PERCENT LEVEL	14
1-PERCENT LEVEL	19

A. BASED ON THE AVERAGE OF 4 REPLICATED PLOTS OF 30 SEEDS EACH.

THE EMERGENCE. THERE WAS NO SIGNIFICANT DIFFERENCE BETWEEN ORTHOCIDE 75 USED AT 1 OUNCE/100 POUNDS OF SEED AND AT 0.5 OUNCES/100 POUNDS OF SEED. FURTHERMORE, NO SIGNIFICANT IMPROVEMENT IN EMERGENCE WAS OBTAINED WHEN ARASAN SF-X WAS APPLIED AT TWO INSTEAD OF ONE OUNCE/100 POUNDS OF SEED. THE SAME CONDITION WAS OBSERVED WHEN THE SAME CHEMICAL WAS USED AT 1 OUNCE AND 0.5 OUNCES RESPECTIVELY PER 100 POUNDS OF SEED. AS THE APPLICATION RATES OF THE CHEMICALS WERE DECREASED, THEIR EFFICACY AS SEED PROTECTANTS ALSO DECREASED. NO INCREASE IN EFFECTIVENESS WAS FOUND WHEN THE CHEMICALS WERE USED IN COMBINATION. ALTHOUGH ORTHOCIDE 75 AND ARASAN SF-X APPEAR TO BE EQUALLY EFFECTIVE IN CONTROLLING PREEMERGENCE DAMPING-OFF, THE EFFECTIVENESS OF ORTHOCIDE 75 WAS HIGHER WHEN THE DOSAGES WERE EQUAL. FURTHER EVIDENCE TO SUBSTANTIATE THIS OBSERVATION MAY BE OBTAINED BY EXAMINING THE RESULTS IN TABLE 6 IN WHICH THE TWO CHEMICALS WERE COMBINED AT DIFFERENT RATES AS COMPARED TO THOSE OF THE EQUIVALENT RATES WHEN USED ALONE.

BEAN EXPERIMENTS

AGROX, VANCIDE 51, ORTHOCIDE 75, SPERGON, SEMESAN, AND ARASAN SF-X WERE SELECTED FOR FURTHER TESTING, ALONE AND IN COMBINATION UNDER TWO SOIL TEMPERATURES (16° - 20°C. AND 20° - 24°C.), ON THE BASIS OF THE RESULTS OBTAINED IN THE PRELIMINARY BEAN EXPERIMENTS.

THE RESULTS ARE PRESENTED IN TABLE 7. THESE RESULTS SHOW THAT ORTHOCIDE 75 WAS THE MOST EFFECTIVE CHEMICAL IN CONTROLLING PREEMERGENCE DAMPING-OFF. THE SAME WAS TRUE FOR ALL OF ITS COMBINATIONS, EXCEPT WHEN ORTHOCIDE 75 WAS MIXED WITH ARASAN SF-X. IN THIS CASE, AS WELL AS WHEN ARASAN SF-X WAS COMBINED WITH SEMESAN (THE ONLY TWO COMBINATIONS

TABLE 7. PERCENTAGE EMERGENCE OF ROUND POD KIDNEY WAX BEAN SEEDLINGS AFTER SEED TREATMENT WITH FUNGICIDES ALONE AND IN COMBINATION, AT LOW (16° - 20°C.) AND HIGH (20° - 24°C.) SOIL TEMPERATURES.

TREATMENT[B]	TOTAL EMERGENCE[A]	
	SOIL TEMPERATURE	
	16° - 20°C.	20° - 24°C.
	PERCENT	PERCENT
AGROX	62	76
AGROX PLUS VANCIDE	79	92
VANCIDE	57	75
AGROX PLUS ORTHOCIDE	89	84
ORTHOCIDE	86	81
AGROX PLUS SPERGON	73	69
SPERGON	39	61
SPERGON PLUS ORTHOCIDE	85	78
SEMESAN	81	77
SEMESAN PLUS ORTHOCIDE	87	82
SEMESAN PLUS SPERGON	72	83
ARASAN	84	85
ARASAN PLUS ORTHOCIDE	79	78
ARASAN PLUS SEMESAN	72	79
NON-TREATED CONTROL	17	61
L. S. D.: 5-PERCENT LEVEL	11	11
1-PERCENT LEVEL	14	14

A. BASED ON THE AVERAGE OF 4 REPLICATED PLOTS OF 30 SEEDS EACH.
B. CHEMICALS USED ALONE AT 2 OZ./100 LB. OF SEED; CHEMICALS USED IN COMBINATION AT 1 OZ./100 LB. OF SEED; EXCEPT FOR VANCIDE WHICH WAS APPLIED AT 4 OZ. AND 2 OZ./100 LB. OF SEED RESPECTIVELY.

TABLE 8. PERCENTAGE OF POSTEMERGENCE DAMPING-OFF OF ROUND RED KIDNEY WAX BEAN SEEDLINGS AT LOW (16° - 20°C.) AND HIGH (20° - 24°C.) SOIL TEMPERATURES AFTER TREATMENT WITH VARIOUS FUNGICIDES ALONE AND IN COMBINATION.

TREATMENT[B]	POSTEMERGENCE DAMPING-OFF[A]	
	SOIL TEMPERATURE	
	16° - 20°C.	20° - 24°C.
	PERCENT	PERCENT
AGROX	5	18
AGROX PLUS VANCIDE	4	13
VANCIDE	7	23
AGROX PLUS ORTHOCIDE	4	22
ORTHOCIDE	7	24
AGROX PLUS SPERGON	10	17
SPERGON	3	18
SPERGON PLUS ORTHOCIDE	3	18
SEMESAN	2	7
SEMESAN PLUS ORTHOCIDE	4	11
SEMESAN PLUS SPERGON	3	18
ARASAN	4	19
ARASAN PLUS ORTHOCIDE	2	19
ARASAN PLUS SEMESAN	1	19
NON-TREATED CONTROL	3	27

A. BASED ON THE AVERAGE OF 4 REPLICATED PLOTS OF 20 SEEDS EACH.
B. CHEMICALS USED ALONE AT 2 OZ./100 LB. OF SEED; CHEMICALS USED IN COMBINATION AT 1 OZ./100 LB. OF SEED; EXCEPT FOR VANCIDE WHICH WAS USED AT 4 OZ. AND 2 OZ./100 LB. OF SEED RESPECTIVELY.

INCLUDING ARASAN) THE EFFECTIVENESS OF THE COMBINATIONS WAS LOWER THAN THAT OF THE SAME CHEMICALS USED ALONE.

THERE WERE NO SIGNIFICANT DIFFERENCES BETWEEN THE EFFECTIVENESS OF ORTHOCIDE 75, ARASAN SF-X AND SEMESAN, EITHER AT LOW (16° - 20°C.) AND OR HIGH (20° - 24°C.) SOIL TEMPERATURES. BUT THE CONTROL AND THE LESS EFFECTIVE CHEMICALS LIKE VANCIDE 51 AND SPERGON, SHOWED SIGNIFICANT DIFFERENCES AT THESE TWO SOIL TEMPERATURE LEVELS, THE LOWER PERCENTAGE OF HEALTHY PLANTS BEING RECORDED AT THE LOW SOIL TEMPERATURE. MORE POST-EMERGENCE DAMPING-OFF WAS OBSERVED IN PLANTS GROWING AT THE HIGH SOIL TEMPERATURES (TABLE 8). IN THIS RESPECT, THE RESULTS WERE SIMILAR TO THOSE OBTAINED WITH PEAS UNDER SIMILAR CONDITIONS (TABLE 3).

IN ORDER TO GIVE THE MOST FAVORABLE CONDITIONS FOR PREEMERGENCE DAMPING-OFF ATTACK, AND THUS OBTAIN A BETTER EVALUATION OF THE CHEMICALS TO BE TESTED, A SECOND BEAN EXPERIMENT WAS CONDUCTED AT THE LOW TEMPERATURE USING AGROX, ORTHOCIDE 75, SPERGON, SEMESAN, AND ARASAN SF-X. THE CHEMICALS WERE APPLIED AT DIFFERENT RATES, ALONE AND IN COMBINATION (TABLE 9).

OF ALL THE CHEMICALS USED ALONE, ORTHOCIDE 75 WAS AGAIN THE MOST EFFECTIVE IN CONTROLLING PREEMERGENCE DAMPING-OFF. RANKING NEXT WERE ARASAN SF-X, AGROX, SEMESAN, AND SPERGON IN ORDER OF DECREASING EFFECTIVENESS. NO INCREASE IN THE EFFICACY OF THE COMBINATIONS WAS OBSERVED IF THE CHEMICALS GAVE GOOD CONTROL WHEN USED ALONE. THERE WERE NO SIGNIFICANT DIFFERENCES BETWEEN ORTHOCIDE 75, ARASAN SF-X,

TABLE 9. PERCENTAGE EMERGENCE OF ROUND POD KIDNEY WAX BEAN SEEDLINGS AFTER TREATMENT WITH FUNGICIDES, USING DIFFERENT DOSAGES AND COMBINATIONS OF CHEMICALS AT LOW (16° - 20°C.) SOIL TEMPERATURES.

TREATMENT, OUNCES PER 100 POUNDS OF SEED	TOTAL EMERGENCE [A]
	PERCENT
AGROX, 2	69
AGROX, 1 PLUS ORTHOCIDE, 1	88
AGROX, 1 PLUS ORTHOCIDE, 0.5	86
ORTHOCIDE, 2	87
ORTHOCIDE, 1	90
SPERGON, 2	47
SPERGON, 4	51
SPERGON, 6	56
ORTHOCIDE, 1 PLUS SPERGON, 1	83
ORTHOCIDE, 0.5 PLUS SPERGON, 2	87
ORTHOCIDE, 0.5 PLUS SPERGON, 3	85
NON-TREATED CONTROL	38
SEMESAN, 2	68
SEMESAN, 1	78
SEMESAN, 1 PLUS ORTHOCIDE, 1	87
SEMESAN, 0.5 PLUS ORTHOCIDE, 0.5	91
SEMESAN, 1 PLUS SPERGON, 1	82
SEMESAN, 0.5 PLUS SPERGON, 2	71
ARASAN, 2	77
ARASAN, 1	81
ARASAN, 1 PLUS ORTHOCIDE, 1	83
ARASAN, 0.5 PLUS ORTHOCIDE, 0.5	84
ARASAN, 1 PLUS SEMESAN, 1	67
ARASAN, 0.5 PLUS SEMESAN, 0.5	52
NON-TREATED CONTROL	36
L.S.D.: 5-PERCENT LEVEL	10
1-PERCENT LEVEL	12

A. BASED ON THE AVERAGE OF 4 REPLICATED PLOTS OF 30 SEEDS EACH.

AND SEMESAN AND THEIR COMBINATIONS WHEN APPLIED AT 2 OUNCES AND AT 1 OUNCE/100 POUNDS OF SEED; NOR BETWEEN THE SPERGON APPLICATIONS WHEN USED AT 2 OUNCES, 4 OUNCES AND 6 OUNCES PER 100 POUNDS OF SEED. THE EFFICACY OF THE ARASAN - SEMESAN COMBINATION WAS AGAIN LOWER THAN THAT OF THE SAME CHEMICALS USED ALONE. NO DECREASE IN EFFECTIVENESS WAS OBSERVED IN THE ARASAN - ORTHOCIDE 75 COMBINATION AS IN THE PREVIOUS BEAN EXPERIMENT.

IN A THIRD EXPERIMENT, ORTHOCIDE 75, ARASAN SF-X, AGROX, AND SEMESAN, THE MOST EFFECTIVE CHEMICALS IN THE PREVIOUS EXPERIMENT, WERE COMPARED ALONE AND IN COMBINATION. RATES WERE THOSE RECOMMENDED BY THE MANUFACTURERS (TABLE 10). THE COMBINATION OF SPERGON PLUS ORTHOCIDE, THE MOST EFFECTIVE COMBINATION INCLUDING SPERGON, WAS ALSO INCLUDED IN THIS EXPERIMENT. ALL THE CHEMICALS AND THEIR COMBINATIONS WERE SIGNIFICANTLY EFFECTIVE IN CONTROLLING PREEMERGENCE DAMPING-OFF, AS COMPARED WITH THE NON-TREATED CONTROL. HOWEVER, AS IN THE PREVIOUS BEAN EXPERIMENTS, THE EFFECTIVENESS OF THE ARASAN - SEMESAN COMBINATION WAS LOWER THAN THAT OF THE SAME CHEMICALS USED ALONE. IT WAS ALSO OBSERVED THAT THE PERCENTAGE OF NORMAL PLANTS IN THE NON-TREATED CONTROL WAS HIGHER THAN IN THE PREVIOUS EXPERIMENT. THIS WAS PROBABLY BECAUSE THE SOIL TEMPERATURE RANGE WAS HIGHER (18.5° - 23°C.) IN THIS EXPERIMENT THAN IN THE PREVIOUS EXPERIMENTS AND CONSEQUENTLY CONDITIONS WERE MORE FAVORABLE FOR THE GERMINATION OF THE BEAN SEEDS.

TABLE 10. PERCENTAGE EMERGENCE OF ROUND POD KIDNEY WAX BEAN SEEDLINGS AFTER SEED TREATMENT WITH FUNGICIDES, USING DIFFERENT DOSAGES AND COMBINATIONS OF CHEMICALS AT LOW (13.5° - 23.0°C.) SOIL TEMPERATURES.

TREATMENT, OUNCES PER 100 POUNDS OF SEED	TOTAL EMERGENCE [A]
	PERCENT
AGROX, 2	67
AGROX, 1 PLUS ORTHOCIDE, 1	87
ORTHOCIDE, 2	84
ORTHOCIDE, 1 PLUS SPERGON, 1	83
SEMESAN, 2	86
SEMESAN, 1 PLUS ORTHOCIDE, 1	85
ARASAN, 2	87
ARASAN, 1 PLUS ORTHOCIDE, 1	91
ARASAN, 1 PLUS SEMESAN, 1	79
NON-TREATED CONTROL	43
L. S. D.: 5-PERCENT LEVEL	15
1-PERCENT LEVEL	19

A. BASED ON THE AVERAGE OF 4 REPLICATED PLOTS OF 30 SEEDS EACH.

DISCUSSION AND CONCLUSIONS

THE OBJECT OF THE PRESENT INVESTIGATION WAS TO STUDY THE EFFECTIVENESS OF A NUMBER OF MERCURIC AND NON-MERCURIC SEED PROTECTANTS IN CONTROLLING SEED DECAY AND PREEMERGENCE DAMPING-OFF ON PEAS AND BEANS, WHEN USED ALONE AND IN COMBINATION AT DIFFERENT DOSAGES AND UNDER TWO SOIL TEMPERATURES.

PRELIMINARY EXPERIMENTS TO FIND THE MOST EFFECTIVE OF THE SEED TREATMENT MATERIALS WERE FOLLOWED BY MORE EXTENSIVE WORK. SEED DECAY AND/OR PREEMERGENCE DAMPING-OFF WAS MOST SEVERE UNDER SOIL TEMPERATURE CONDITIONS THAT WERE UNFAVORABLE FOR SEED GERMINATION AND NORMAL GROWTH OF THE SEEDLINGS, AND FAVORABLE FOR THE DEVELOPMENT OF SOIL PATHOGENIC ORGANISMS. THIS WAS IN AGREEMENT WITH THE RESULTS OF LEACH (22) WHO FOUND THAT "PREEMERGENCE INFECTION WAS MOST SEVERE AT TEMPERATURES THAT WERE RELATIVELY LESS FAVORABLE TO THE HOST THAN TO THE PATHOGEN AS MEASURED BY THE RATIO OF THEIR GROWTH RATES." PEA, A LOW TEMPERATURE CROP, SUFFERED MORE SEVERE SEED DECAY AND PREEMERGENCE DAMPING-OFF AT HIGH SOIL TEMPERATURES (20° - 24°C.) THAN AT LOW SOIL TEMPERATURE (16° - 20°C.). THE REVERSE WAS TRUE FOR BEANS, A HIGH TEMPERATURE CROP. THIS CAN BE EXPLAINED ON THE BASIS OF A RETARDATION IN THE GERMINATION OF THE SEEDS BECAUSE OF UNFAVORABLE SOIL TEMPERATURES, THUS GIVING THE SOIL PATHOGENIC ORGANISMS A LONGER TIME TO ATTACK THE SEED AND THE SEEDLINGS.

THE ORGANISMS ISOLATED FROM DISEASED PEA SEEDLINGS GROWING AT LOW SOIL TEMPERATURES (16° - 20°C.) AND HIGH SOIL TEMPERATURES (20° - 24°C.) WERE SIMILAR TO THOSE OBTAINED BY OTHER INVESTIGATORS (5, 16, 22, 23). BAYLIS (5), TESTING SEVERAL FUNGI ISOLATED FROM COTYLEDONS AND DISEASED EMBRYOS OF PEAS, FOUND THAT SPECIES OF PYTHIUM AND SPECIES OF FUSARIUM WERE THE ONLY ORGANISMS CAPABLE OF INHIBITING EMERGENCE OF SEED PEAS, THE DISEASE BEING ATTRIBUTED EXPECIALLY TO PYTHIUM SPP.. JACKS (16) FOUND PYTHIUM SPP., FUSARIUM SPP. AND RHIZOCTONIA SPP. AS THE MOST COMMONLY ISOLATED FUNGI FROM DISEASED SEEDLINGS OF PEA. PYTHIUM SPP. WAS THE MOST COMMON AT LOW SOIL TEMPERATURES AND FUSARIUM SPP. AT HIGH SOIL TEMPERATURES. RHIZOCTONIA SOLANI WAS ISOLATED FROM MOST SEEDS. LEACH AND SMITH (23) NAMED SPECIES OF PYTHIUM, RHIZOCTONIA, FUSARIUM, AND OTHER SIMILAR SOIL ORGANISMS RESPONSIBLE FOR SEED DECAY AND SEEDLING ROT. LEACH (22) FOUND THAT IN PYTHIUM INFESTED SOIL, SEED DECAY AND PREEMERGENCE DAMPING-OFF INFECTION OF PEAS WAS MOST SEVERE BETWEEN 12 AND 25°C.. HE OBSERVED ALSO THAT A LOW TEMPERATURE ORGANISM CAUSED MORE SEVERE INFECTION AT A LOW THAN AT A HIGH SOIL TEMPERATURE, AND THAT WITH A HIGH TEMPERATURE ORGANISM, THE REVERSE WAS TRUE. REINKING (32), REPORTED THAT SPECIES OF FUSARIUM, PYTHIUM, APHANOMYCES, RHIZOCTONIA, AND ASCOCHYTA WERE THE ORGANISMS PRIMARLY RESPONSIBLE FOR PEA DAMPING-OFF. FUSARIUM SOLANI V. MARTII F. AND PYTHIUM ULTIMUM WERE SHOWN TO MULTIPLY IN THE SOIL WITH REPEATED PEA PLANTINGS.

FUSARIUM SPP. WERE THE MOST PREVALENT ORGANISMS ISOLATED FROM PEA SEEDLINGS GROWING UNDER HIGH SOIL TEMPERATURE CONDITIONS (20° - 24°C.). JONES (18), STUDYING STEM AND ROOT-ROT OF PEAS CAUSED BY SPECIES OF FUSARIUM, FOUND ALSO THAT THE ORGANISM PREFERS A SOIL TEMPERATURE ABOVE

18° C., WITH KILLING OF THE PLANT TAKING PLACE AT 24°C. IN ADDITION, THE SAME AUTHOR REPORTED THAT THE ORGANISM is NOT MUCH AFFECTED BY VARIATIONS IN SOIL MOISTURE WITHIN THE LIMITS FAVORABLE FOR PLANT GROWTH. THE EXPERIMENTAL WORK REPORTED HEREIN CORROBORATES THESE FINDINGS IN PART. THERE WAS A HIGHER PERCENTAGE OF POSTEMERGENCE DAMPING-OFF IN BOTH PEAS AND BEANS (TABLES 3 AND 8) IN PLANTS GROWN AT THE HIGH THAN AT LOW SOIL TEMPERATURES.

ALTHOUGH JACKS (16) REPORTED THAT SEED TREATMENT DOES NOT ORDINARILY GIVE PROTECTION AGAINST POSTEMERGENCE DAMPING-OFF, HE NOTED THAT THE FUNGICIDES APPEARED TO BRING SOME INCREASE IN VIGOUR TO THE SEEDLINGS WHICH ENABLED THEM TO SURVIVE PREEMERGENCE AND POSTEMERGENCE DAMPING-OFF ATTACK. WITH HIGHLY SUSCEPTIBLE HOSTS, SUCH AS THE VARIETIES OF PEA AND BEAN USED IN THE PRESENT INVESTIGATION; WITH PLENTIFUL PATHOGENIC SOIL ORGANISMS, AS SHOWN BY THE RESULTS OF ISOLATIONS MADE FROM DISEASED SEEDLINGS; AND WITH ENVIRONMENTAL (SOIL TEMPERATURE AND MOISTURE) CONDITIONS FAVORABLE FOR THE DEVELOPMENT OF THE PATHOGENS, THE IDEAL CONDITIONS FOR THE DEVELOPMENT OF PREEMERGENCE DAMPING-OFF WAS SECURED. UNDER SUCH CONDITIONS, IT WAS POSSIBLE TO MAKE A BETTER EVALUATION OF THE EFFECTIVENESS OF THE CHEMICALS TESTED.

REPORTS ON TOXIC EFFECTS OF SEVERAL FUNGICIDES ON TREATED SEED HAVE BEEN MADE BY SEVERAL AUTHORS (1, 3, 8, 25). ALSO SEVERAL ENVIRONMENTAL FACTORS SUCH AS SOIL MOISTURE AND SOIL TEMPERATURE HAVE BEEN FOUND TO CAUSE WIDE VARIATIONS IN THE EFFECTIVENESS OF THE CHEMICALS USED AS SEED PROTECTANTS (13, 14, 16, 18). IT WAS THOUGHT THAT A COMPARISON BETWEEN THE EFFICACY OF CHEMICALS USED ALONE AND IN COM-

BINATION, UNDER DIFFERENT CONDITIONS OF SOIL TEMPERATURE, WOULD REVEAL DIFFERENCES IN EFFICIENCY. THE FIRST REPLICATED EXPERIMENTS IN WHICH THE CHEMICALS WERE TESTED AT THE SAME TIME UNDER TWO SOIL TEMPERATURES SHOWED THAT IN BOTH PEAS AND BEANS THERE WERE NO SIGNIFICANT DIFFERENCES BETWEEN THE EFFECTIVENESS OF THE FUNGICIDES WHEN USED AT LOW AND AT HIGH SOIL TEMPERATURES. THERE WERE SIGNIFICANT DIFFERENCES BETWEEN NON-TREATED SEEDS AND THOSE TREATED WITH THE LESS EFFECTIVE CHEMICALS IN THE BEAN EXPERIMENTS, THE LOWER PERCENTAGE OF HEALTHY PLANTS BEING RECORDED AT THE LOW SOIL TEMPERATURES. AT THE LOW SOIL TEMPERATURE, GERMINATION WAS DELAYED RESULTING IN AN INCREASED AMOUNT OF SEED DECAY AND PRESEMERGENCE DAMPING-OFF, IF THE CHEMICAL APPLIED WAS NOT AN EFFECTIVE PROTECTANT. THIS WAS THE CASE WITH VANCIDE 51 AND SPERGON. THIS CAN READILY EXPLAIN, AS SHOWN IN TABLE 7, THE DIFFERENCES BETWEEN THE EFFECTIVENESS OF THE CHEMICALS AS SEED PROTECTANTS AT THE LOW AND AT THE HIGH SOIL TEMPERATURES. ALTHOUGH THESE DIFFERENCES WERE NOT AS SIGNIFICANT IN THE PEA EXPERIMENTS (TABLE 2), SIMILAR VARIATIONS WERE OBSERVED, I.E., THE HIGHER POSTEMERGENCE DAMPING-OFF OCCURRED UNDER HIGH SOIL TEMPERATURE CONDITIONS (TABLE 3).

No differences in effectiveness of the chemicals used alone, compared their combination use were found in any of the pea and bean experiments. In general, the chemicals in combination were only as effective as the better of the two chemicals when used alone. For example, in Table 7, the percentage emergence of bean seed treated with Semesan plus Orthocide 75 was 87, while for Semesan alone it was 81 and for Orthocide 75 alone it was 86. The same table shows that the percentage emergence of seeds treated with Spergon alone was 39; those treated with Orthocide 75 gave 87-percent seedling emergence, and the combination

OF BOTH CHEMICALS, 85-PERCENT. THUS IT APPEARS THAT THE EFFECTIVENESS OF THE COMBINATIONS IS DIRECTLY RELATED TO THE EFFECTIVENESS OF THE SAME MATERIALS USED ALONE, THE GREATER THE EFFECTIVENESS OF THE CHEMICALS WHEN USED ALONE, THE GREATER THE EFFICACY OF THEIR COMBINATIONS.

THERE WERE SOME CASES IN WHICH THE EFFECTIVENESS OF THE COMBINATIONS WAS LESS THAN THAT OF EITHER ONE ALONE. THIS WAS OBSERVED ONLY IN THE BEAN EXPERIMENTS. THE COMBINATIONS OF ARASAN SF-X, A NON-MERCURIC FUNGICIDE, AND SEMESAN, A MERCURIC FUNGICIDE, WERE LESS EFFECTIVE IN CONTROLLING DAMPING-OFF THAN WERE EITHER USED ALONG (TABLES 9 AND 10). THE SAME EFFECT WAS OBSERVED WHEN THE CHEMICALS WERE TESTED AT THE SAME TIME UNDER TWO SOIL TEMPERATURE CONDITIONS AS SHOWN IN TABLE 7. ALTHOUGH IN ONE BEAN SEED TREATMENT EXPERIMENT THE ARASAN SF-X-ORTHOCIDE 75 COMBINATION WAS LESS EFFECTIVE THAN THE SAME CHEMICALS USED ALONE (TABLE 7), THIS REACTION WAS NOT OBSERVED IN THE REST OF THE EXPERIMENTS.

SEVERAL FUNGICIDES WERE EFFECTIVE IN CONTROLLING PREEMERGENCE DAMPING-OFF IN PEAS AND BEANS BUT ORTHOCIDE 75 WAS BY FAR THE MOST EFFECTIVE THROUGHOUT ALL THE EXPERIMENTS. THE SAME WAS TRUE FOR ALL THE COMBINATIONS INCLUDING THIS CHEMICAL. THESE RESULTS ARE ACCORDING TO THOSE OBTAINED BY ANDERSEN AND DEZEEUW[A] WHO FOUND ORTHOCIDE 75 TO BE THE MOST EFFECTIVE CHEMICAL FOR CONTROLLING SEED DECAY AND PREEMERGENCE DAMPING-OFF OF ALDERMAN PEAS AND ROUND POD KIDNEY WAX BEANS. THEY COMPARED ORTHOCIDE 75 WITH TWENTY-EIGHT SEED PROTECTANTS INCLUDING SEMESAN, ORTHO SEED GUARD, C & C L-224, VANCIDE 51, AGROX, ARASAN SF-X, SPERGON, AND OTHERS IN THE FIELD.

A. UNPUBLISHED FIELD DATA.

SPERGON, REPORTED AND RECOMMENDED AS AN EFFECTIVE SEED PROTECTANT FOR PEAS AND BEANS BY OTHERS (8, 10, 14, 23, 28, 34, 35), WAS RELATIVELY INEFFECTIVE IN THESE EXPERIMENTS AS COMPARED WITH THE OTHER FUNGICIDES TESTED. IN SOME CASES, EVEN WHEN APPLIED AT DOUBLE THE RATE RECOMMENDED BY THEMANUFACTURERS (TABLE 5), IT WAS NOT EFFECTIVE AGAINST DAMPING-OFF. RECENTLY, ANDERSEN AND DEZEEUW (1, 2) AND WALLEN (40) REPORTED SIMILAR RESULTS REGARDING LOW EFFICACY OF SPERGON AS A SEED PROTECTANT. MCNEW AND MCCALLAN (30) EXPLAINED THIS FACT BY CONSIDERING THAT THE SOIL TEXTURE AND ALKALINITY MAY BE LIMITABLE FACTORS WHICH INFLUENCE THE EFFECTIVENESS OF SPERGON AS A GOOD SEED PROTECTANT.

IN GENERAL, ARASAN SF-X, AGROX, SEMESAN, AND C & C L-224 WERE EQUALLY EFFECTIVE IN CONTROLLING PREEMERGENCE DAMPING-OFF IN PEAS EITHER WHEN USED ALONE OR IN COMBINATION. IN BEANS, HOWEVER, THERE WERE NO SIGNIFICANT DIFFERENCES IN THE EFFECTIVENESS OF ORTHOCIDE 75, ARASAN SF-X, AND SEMESAN WHEN APPLIED AT DIFFERENT RATES BESIDES THOSE RECOMMENDED BY THE MANUFACTURERS. AGROX, ALTHOUGH SIGNIFICANTLY LESS EFFECTIVE, WAS SHOWN TO BE SATISFACTORY FOR CONTROLLING PREEMERGENCE DAMPING-OFF ON BEANS.

IN PEAS, THERE WAS NO SIGNIFICANT DIFFERENCE BETWEEN ORTHOCIDE 75 WHEN APPLIED AT 2 OUNCES AND AT 1 OUNCE/100 POUNDS OF SEED (TABLE 4). EVEN AT 0.5 OUNCES/100 POUNDS OF SEED, ORTHOCIDE 75 WAS AN EFFECTIVE SEED PROTECTANT (TABLE 5). THE SAME RESPONSE WAS NOTED WITH ARASAN SF-X (TABLE 6). THE REVERSE WAS TRUE FOR THE LESS EFFECTIVE CHEMICALS. THUS, AS SHOWN IN TABLE 4, THE EFFICACY OF SPERGON WAS SIGNIFICANTLY INCREASED WHEN APPLIED AT 4 OUNCES AS COMPARED TO 2 OUNCES/100 POUNDS OF SEED.

IN GENERAL, WITH THE MOST EFFECTIVE CHEMICALS, LIKE ORTHOCIDE 75 AND ARASAN SF-X, NO SIGNIFICANT INCREASE IN STAND WAS OBSERVED BY VARYING THE APPLICATION RATES.

IT APPEARS THAT NO ADDITIONAL BENEFITS CAN BE DERIVED FROM THE APPLICATION OF COMBINATIONS OF FUNGICIDES USED IN THESE INVESTIGATIONS. THIS DOES NOT EXCLUDE THE POSSIBILITY THAT OTHER CHEMICALS, WHICH WERE NOT INCLUDED IN THIS PROGRAM, WOULD BE EFFECTIVE. BUT SINCE THE MOST EFFECTIVE FUNGICIDES WERE INCLUDED IN THESE STUDIES, AND SINCE THE LESS EFFECTIVE CHEMICALS WHICH WERE INCLUDED DID NOT EFFECTIVELY CONTROL DAMPING-OFF WHEN USED ALONE OR IN COMBINATION, THE CHANCES OF OBTAINING A SUITABLE COMBINATION BETTER THAN EITHER CHEMICAL ALONE, APPEARS VERY UNCERTAIN.

SUMMARY

1. Several seed protectants were selected and tested alone and in combination, in preliminary experiments on Alderman peas and Round Pod Kidney Wax beans under greenhouse conditions at two soil temperatures.

2. The most promising fungicides were retested in a series of subsequent experiments, both on peas and beans, at low (16° - 20°C.) and at high (20° - 24°C.) soil temperatures. Variations in combinations and application rates, below or above those recommended by the manufacturers, were made throughout all the experiments.

3. Several chemicals were effective in controlling preemergence damping-off in peas and beans, but Orthocide 75 (Captan) was by far the most effective. Ranking next to Orthocide 75 were Arasan SF-X, Agrox, Semesan, and C & C L-224. Spergon, generally recommended for pea and bean seed treatment, was relatively ineffective in these tests.

4. No increase in the effectiveness of the chemicals tested was observed by combining them, if when used alone they gave good preemergence damping-off control. In general, the greater the effectiveness of the chemicals when used alone, the greater the efficacy of their combinations. Furthermore, the fungicides and their combinations were equally effective when used under low and high soil temperature conditions.

5. In all the bean seed treatment experiments, the effectiveness of the combination Arasan SF-X and Semesan was lower than when these chemicals were applied separately. The same reaction was noted in only one

OF THE BEAN EXPERIMENTS WHEN ARABAN SF-X WAS COMBINED WITH ORTHOCIDE 75.

6. PREEMERGENCE DAMPING-OFF WAS MORE SEVERE WHEN THE SOIL TEMPERATURE CONDITIONS WERE LESS FAVORABLE FOR SEED GERMINATION AND NORMAL GROWTH OF THE SEEDLINGS. UNDER SUCH CONDITIONS, SEED GERMINATION AND SEEDLING EMERGENCE WAS DELAYED, GIVING THE SOIL PATHOGENIC ORGANISMS A LONGER TIME TO ATTACK THE SEEDS. POSTEMERGENCE DAMPING-OFF WAS MORE COMMON, BOTH IN PEAS AND BEANS, AT HIGH SOIL TEMPERATURES (20° - 24°C.) THAN AT LOW SOIL TEMPERATURES (16° - 20°C.).

7. WHEN ISOLATIONS WERE MADE FROM DISEASED PEA SEEDLINGS GROWN AT THE TWO SOIL TEMPERATURES, PYTHIUM SPP. WERE THE MOST ABUNDANT ORGANISMS AT THE LOW SOIL TEMPERATURE, AND FUSARIUM SPP. AND RHIZOCTONIA SPP. WERE THE LEAST NUMEROUS. AT THE HIGH SOIL TEMPERATURES, FUSARIUM SPP. WERE MOST PREDOMINANT, FOLLOWED BY RHIZOCTONIA SPP. AND PYTHIUM SPP..

8. PREEMERGENCE DAMPING-OFF AND SEED DECAY OF PEAS AND BEANS CAN BE SUCCESSFULLY CONTROLLED BY SEED TREATMENT.

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Explanation of Plates

The Plates show the relative effectiveness of various fungicides when used alone and in combination at different dosages, in controlling seed decay and preemergence damping-off in Alderman peas. The peas were grown under high soil temperature conditions (20° - 24°C.) in the greenhouse and the pictures were taken fourteen days after planting. The photographs are from the same experiment (Table 4). Each treatment plot consists of two rows and the rates of application are in ounces/100 pounds of seed, after the fungicide.

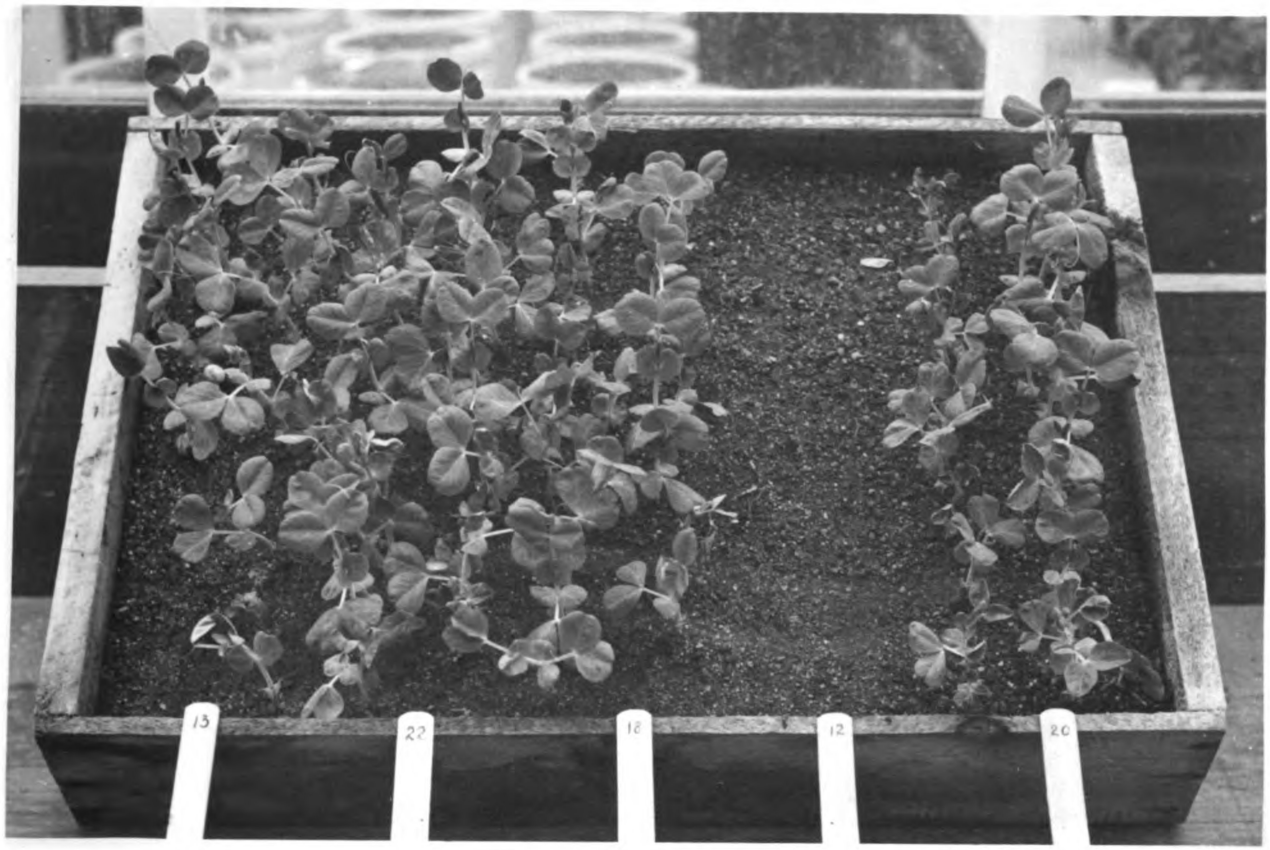

PLATE I

COMPARISON BETWEEN THE NON-TREATED CONTROL AND SOME OF THE MOST EFFECTIVE FUNGICIDES USED ALONE AND IN COMBINATION.

FROM LEFT TO RIGHT :

No. 13. SEMESAN, 2

No. 22. ARASAN SF-X, 1 PLUS SPERGON, 1

No. 18 C & C L-224, 1 PLUS ARASAN SF-X, 1

No. 12. NON-TREATED CONTROL

No. 20. ARASAN SF-X, 1 PLUS ORTHOCIDE 75, 1

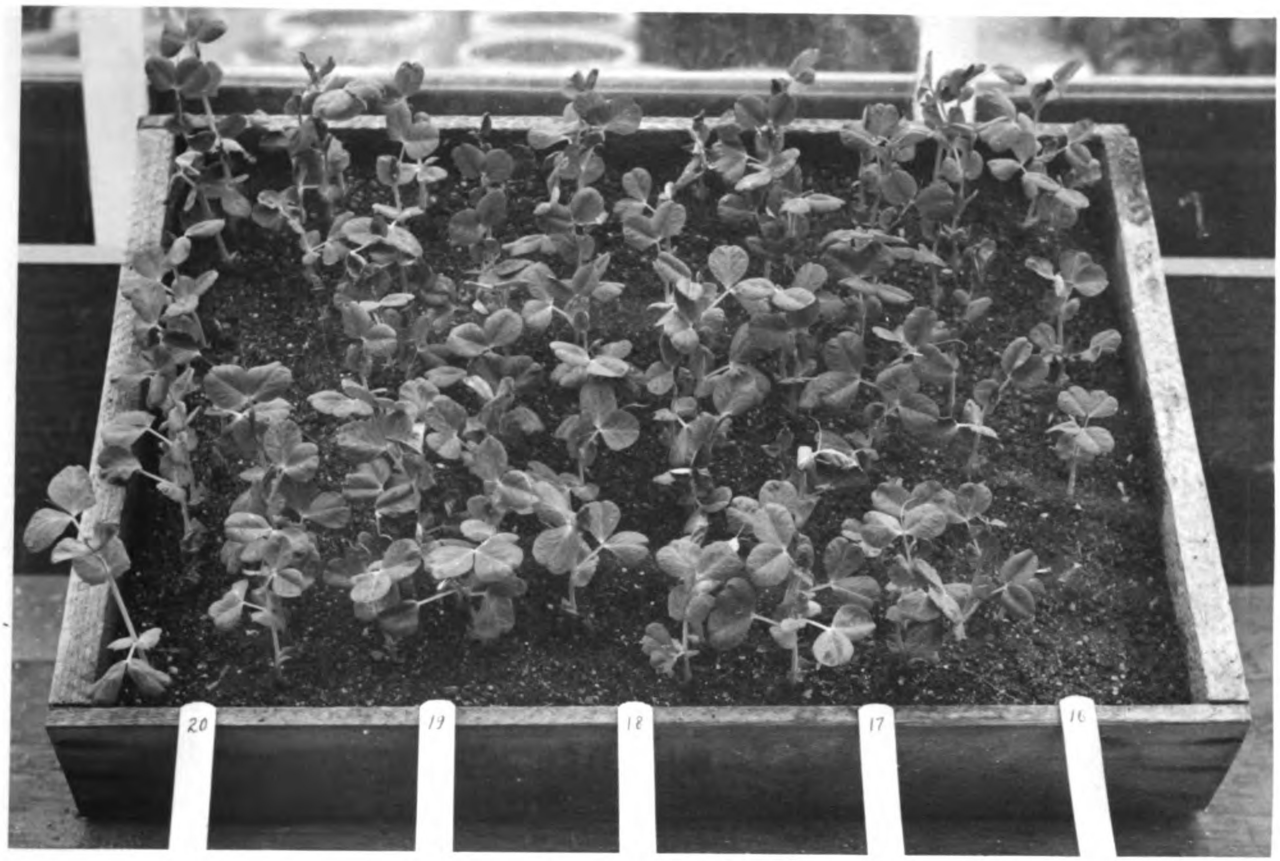

PLATE II

SEEDLING EMERGENCE AFTER SEED TREATMENT WITH SOME OF THE MOST EFFECTIVE CHEMICALS APPLIED ALONE AND IN COMBINATION.

FROM LEFT TO RIGHT:

No. 20. ARASAN SF-X, 1 PLUS ORTHOCIDE 75, 1

No. 19. ARASAN SF-X, 1 PLUS ORTHOCIDE 75, 0.5

No. 18. C & C L-224, 1 PLUS ARASAN SF-X, 1

No. 17. ARASAN SF-X, 2

No. 16. C & C L-224, 2

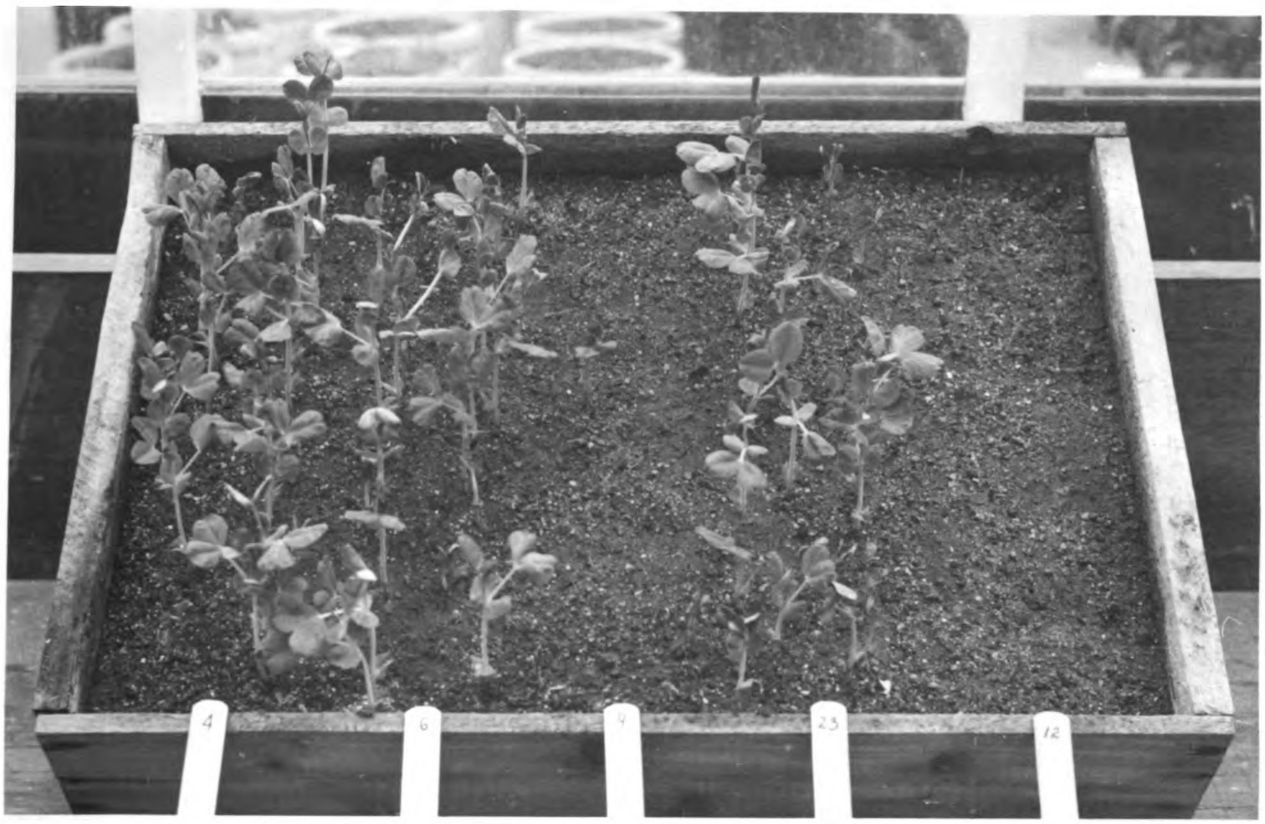

PLATE III

EFFECTIVENESS OF SPERGON AND SOME OF ITS COMBINATIONS AS COMPARED WITH THE NON-TREATED CONTROL.

FROM LEFT TO RIGHT:

No. 4. ORTHOCIDE 75, 2

No. 6. AGREX, 1 PLUS SPERGON, 2

No. 9. SPERGON, 2

No. 23. SPERGON, 2 PLUS ORTHOCIDE 75, 0.5

No. 12. NON-TREATED CONTROL

PLATE IV

EFFECTIVENESS OF ORTHOCIDE 75 AS COMPARED WITH THE NON-TREATED CONTROL AND SOME OTHER TREATMENTS.

FROM LEFT TO RIGHT:

No. 6. ARPEX, 1 PLUS SPERGON, 2

No. 24. SPERGON, 1 PLUS ORTHOCIDE 75, 1

No. 13. SEMESAN, 2

No. 25. NON-TREATED CONTROL

No. 5. ORTHOCIDE 75, 1

PLATE V

COMPARISON BETWEEN SPERGON USED ALONE AND IN COMBINATION WITH AGROX, AT TWO DIFFERENT APPLICATION RATES.

FROM LEFT TO RIGHT:

No. 10. SEMESAN, 1 PLUS ORTHOCIDE 75, 0.5

No. 9. SPERGON, 2

No. 8. SPERGON, 4

No. 7. AGROX, 1 PLUS SPERGON, 1

No. 6. AGROX, 1 PLUS SPERGON, 2