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SPRAY ADDITIVES AND CHEMICAL HARVEST

AIDS FOR NAVY BEAN (Phaseolus vulgaris)

AND POTATO (Solanum tuberosum)

presented by

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SPRAY ADDITIVES AND

CHEMICAL HARVEST AIDS FOR

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BY

DALE ROBERT MUTCH

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ABSTRACT

SPRAY ADDITIVES AND CHEMICAL HARVEST AIDS FOR

NAVY BEAN (*Phaseoulus vulgaris*)

AND

POTATO (*Solanum tuberosum*)

BY

DALE ROBERT MUTCH

Chemical harvest aids are an important management practice for potato (*Solanum tuberosum* L.) vine desiccation. At present, no chemical harvest aids are registered for use on navy bean (*Phaseoulus vulgaris* L.) in Michigan, although prevailing weather conditions would frequently favor their use.

Greenhouse and field experiments were conducted to evaluate ametryn (2-ethylamino)-4-(isopropylamino)-6-(methylthio)-*s*-triazine), endothall (7-oxabicyclo (2,2,1,) heptane-2,3-dicarboxylic acid), dinoseb (2-*sec*-butyl-4,6-dinitrophenol), and paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) as potential chemical harvest aids for navy bean. Dinoseb alone caused little or no desiccation. Ametryn, endothall, and paraquat individually showed moderate desiccation.

Inclusion of additives to herbicide sprays increased their efficacy. The three-way combination of ammonium sulfate plus crop oil markedly increased efficacy of herbicides ametryn, endothall, and dinoseb. The two-way combination of paraquat plus ammonium sulfate resulted in the greatest navy bean desiccation.

Greenhouse and field experiments were conducted to evaluate additives to increase efficacy of dinoseb and endothall for potato vine desiccation. Inclusion of additives resulted in slight increases in endothall efficacy, however, desiccation was still poor. The three-way combination of dinoseb, plus ammonium sulfate, plus crop oil markedly increased desiccation of potato vines.

In this study, paraquat showed the most promise as a chemical harvest aid on navy bean. Ammonium sulfate at 9.0 kg/ha increased efficacy of paraquat in the greenhouse and in the field. Field studies indicate that paraquat at 0.6 kg/ha in combination with ammonium sulfate at 9.0 kg/ha have no adverse effects on navy bean germination or seed dry weight.

The three-way combination of ammonium sulfate plus crop oil plus dinoseb can increase desiccation of potato vines without detrimental effects on tuber quality. The combination of 9.0 kg/ha ammonium sulfate plus crop oil at 2.3 L/ha plus 1.4 kg/ha dinoseb gave equivalent potato vine kill for 'Sebago' to 2.8 kg/ha dinoseb plus 2.3 L/ha crop oil.

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TABLE OF CONTENTS

LIST OF TABLES

Table | Page

Chapter 2

INTRODUCTION

A chemical harvest aid is an agricultural chemical which desiccates or defoliates existing vegetation to facilitate an early or more timely harvest of a crop. The need for chemical crop desiccation is enhanced by prolonged wet periods in the Fall prior to harvest, or when other management practices cause delay in normal maturity. Navy bean (*Phaseolus vulgaris* L.), potato (*Solanum tuberosum* L.) (12), soybean (*Glycine max Merr* L.) and sunflower (*Helianthus annuus* L.) (3,5), are crops in Michigan where the use of a chemical harvest aid could be beneficial. In Michigan, four contact herbicides are registered for potato vine killing. Ametryn (2-(ethylamino)-4-isopropylamino-6-methylthio)-*s*-triazine), endothall (7-oxabicyclo(2,2,1)heptaine-2,3-dicarboxylic acid), dinoseb (2-*sec*-butyl-4,6-dinitro phenol), and paraquat (1,1'-dimethyl-5,5'-bipyridinium ion) (35).

Michigan is the largest producer of navy beans in the United States (24) and, currently, there are no registrations for use of chemical harvest aids. However, in 1977, when Michigan had a wet Fall, approximately 70,000 acres were not harvested (24), a condition when a chemical harvest aid could have reduced this loss.

In a recent survey, 67% of Michigan potato growers indicated they used dinoseb for chemical vine desiccation (28). Paraquat causes rapid vine kill, however, current registration prohibits its use on potatoes to be stored or used for seed.

Paraquat has received a state label (24c) registration as a harvest aid for soybean (3). Paraquat has also been used to accelerate drying for sunflower (3,5).

Herbicides used for desiccation purposes are generally contact herbicides and more toxic to humans (35). Research with these compounds should employ different techniques to increase their efficacy while decreasing their rates.

The purpose of this research was to (a) evaluate several potential chemical harvest aids and to determine efficacy of various ammonium salts and ethephon (2-chloroethyl) phosphonic acid) as additives for increasing efficacy on navy bean, (b) evaluate several ammonium salts and ethephon as additives to increase efficacy of dinoseb and endothall for potato vine desiccation.

Chapter 1

Literature Review

History of Harvest Aids

The value of early harvest of potatoes facilitated by vine removal was recognized by Murphy (25), and Schultz and Folsom (27) in 1920. Research developed on the subject in the 1930's and 1940's.

Tuber cracking during harvest of potatoes was observed in the earlier work with vine killing. Werner and Dutt, in 1940, reported that root cutting or vine killing reduced cracking of late variety "Triumph" potatoes (37). Many advantages for potato vine desiccation were reported by Callbeck (15), desiccation prevented tuber infection by late blight, prevented spread of virus diseases, reduced number of oversized and knobby tubers, speeded skin maturity, and facilitated and permitted timing of harvest. Binkley and Kunkel (8) reported increased use of vine killers in Colorado for the purpose of toughening tuber skins, and to reduce scuffing and mechanized abrasions.

In Maine, potatoes must be harvested during September and early October to prevent possible losses to tubers by low temperatures (16). When killing frosts do not occur, potato vines must be killed or potatoes must be harvested with green vines. If late blight is present, considerable losses can occur from late blight tuber rot when potatoes are harvested with infected green vines (12). Vines need to be killed two weeks prior to harvest to prevent tuber skinning, or bruising (7).

Hand pulling of potato vines was the first method of destroying vegetative growth (7). However, as acreage increased, this method soon became impractical. Woolery Machine Company developed a flame potato vine burner which used 18 gallons of fuel per acre. Roto-beating of vines became a practice of killing green vine growth (23). These practices, however, were unsatisfactory.

The chemical revolution was just beginning in the 1940's. Such compounds as sulfuric acid and copper sulfate were used experimentally for potato vine desiccation (2). In the late 1940's and early 1950's, ammonium sulfate was evaluated by potato researchers as a potential chemical harvest aid at rates of 200 to 300 pounds per acre (26,30). Vine killing with chemicals became an accepted practice with the development of more complex organic compounds such as substituted phenols and endothall (7-oxabicyclo 2,2,1 heptane-2,3-dicarboxylic acid) (2). The use of additives to increase efficiency of herbicides was reported by Callbeck (15), who used crank case oil in combination with handy killer, green cross topkiller, and Geigy's potato vine killer; (all sodium arsenite compounds).

In 1946, Steinbauer (31) reported occasional discoloration in the vascular bundles of tubers from vines treated with sodium nitrate, dinitrocresol, and phenol compounds. Other researchers also reported vascular discoloration in tubers following use of chemical harvest aids (12,15). Prince (26) reported that discoloration was confined to the xylem elements of the vascular ring with the discoloration being more dense on the stem side of the vessel end walls. Some early investigations confused stem end browning with vascular discoloration (16). Folsom and Rich (18) developed a "half-inch or 1.3 cm depth" method of cutting tubers to separate stem end browning from vascular discoloration. Vascular discoloration extends greater than 1.3 cm from point of stolon attachment, where stem end browning is confined to the stem end portion of the tuber (18).

Early researchers concluded that rapid vine killing resulted in vascular discoloration (16). However, Hoyman (21) reported that discoloration was caused by climatic conditions. Hoyman showed that drought in combination with rapid vine desiccation resulted in discoloration (21).

Cotton (Gossypium hirsutum L.) has also been considered as a potential crop for chemical harvest aids. Tharp (34) in 1955, reported 2,968,973 acres of cotton were treated with defoliants or desiccants. Desiccation or defoliation of cotton was important to prevent green staining of the fibers (2). Barnes (7) reported that chemical harvest aids may also be valuable for soybeans grown for seed. Chemical harvest aids have also been shown to reduce seed moisture in rice (Oryza sativa L.) (20). Harvest aids applied to alfalfa (Medicago sativa L.), various clovers (Trifolium L.), and birdsfoot trefoil (Lotus corniculatns L.) reduced pod shattering when harvested for seeds (22).

Several contact herbicides are now registered in Michigan for potato vine desiccation. Phytobland oils or organic solvents are recommended in combination with these herbicides to increase their efficacy. With increased profits available from earlier harvests, the use of chemical harvest aids has expanded to crops like soybean, sunflower, and navy bean (5).

Use of Ammonium Salts and Ethephon to Influence Herbicide Efficacy

Ammonium sulfate, ammonium sulfamate, and ammonium thiocyanate, applied at high rates have been classified as herbicides (4). However, using ammonium salts at low non-herbicidal rates in combination with herbicides has increased herbicide efficacy.

Amitrol-T is a commercial product combining amitrole (3-amino-*s*-triazole) with ammonium thiocyanate (35). Ammonium thiocyanate increased amitrole translocation in quackgrass (*Agropyron repens* L.) (16). Ammonium ions could affect absorption and translocation of picloram (4-amino-3,5,6-trichloropicolinic acid) in quava (*Psidium guajava* L.) and dwarf bean (17). Ammonium sulfate increased efficacy of bentazon (3-isopropy-1*H*-2,1,3 benzothiadizain-(4)-3*H*-one, 2,2-dioxide) and glyphosate (N-(phosphonomethyl) glycine) for yellow nutsedge (*Cyperus esculentus* L.) control (33). Glyphosate activity was enhanced when ammonium sulfate was used as an additive for purple nutsedge (*Cyperus rotundus* L.) (32) and quackgrass control (10).

Early researchers hypothesized that the ammonium ions decreased the pH of the herbicide spray, thus increasing absorption (29). However, Wilson and Nishimoto (39) reported that enhancement of picloram absorption was not necessarily due to lowering the pH of the herbicide solution. In addition, varying the pH of the spray solutions of bentazon and glyphosate after addition of ammonium salts resulted in no difference in efficacy of these herbicides for yellow nutsedge control (33).

It has been reported by Good and Izawa (19) that ammonium ions and methylamine prevent phosphorylation and increase the rate of electron flow from plastoquinone to photosystem I. Herbicides and ammonium ions may act at the same sites to increase desiccation to the plant. Paraquat (1,1'-dimethyl-4,4'-bipyridium ion) removes electrons from the electron transport system of photosystem I, thus inhibiting the reduction of NADP to NADPH (14).

However, herbicides and ammonium ions may also react at different sites, but the combination may enhance the herbicidal effect. Suwanketnikom (33), reported that single applications of bentazon at 1.1 kg/ha did not provide adequate control of yellow nutsedge. However, bentazon activity was greatly enhanced with the addition of ammonium salts. Boger et al. (11) concluded that bentazon inhibited electron flow in photosystem II.

Weissman (36) reported that ammonium ions suppressed both nitrate and nitrite reductase levels in plant leaves, and may cause an increase of nitrite accumulation. Ammonium ions, when applied in combination with herbicides, may cause increased nitrite accumulation in plant leaves above that for the herbicide applied alone.

Ethephon (2-chloroethyl phosphonic acid) has enhanced dicamba (2,6-dichloro-o-anisic acid) efficacy (9). Ethephon increased basipetal translocation of ^{14}C glyphosate in yellow nutsedge (33). This report supports Binning et al. (9) hypothesis that ethelene released from ethephon may alter source-sink relationships in plants and increase basipetal movement of herbicides.

Current Need for Chemical Harvest Aids

In Michigan, a chemical harvest aid would be beneficial if detrimental weather delayed planting and/or harvest. Chemical harvest aids have been shown to reduce moisture content in soybean (38), sunflower (5), and rice seed (20). Byg et al. (13) reported safe harvest of short season soybeans at 13-14% seed moisture 4 to 5 days earlier if paraquat was applied as a chemical harvest aid.

Paraquat has received a (24C) state label in Ohio and Michigan for use as a chemical harvest aid for soybeans (3). Paraquat has shown no adverse effects on germination of soybeans (38). An early harvest and market delivery of soybeans brings a premium price providing an incentive for use of chemical harvest aids. In addition, the longer a crop stays in the field, the greater the danger of inclement weather (5).

United States sunflower acreage has expanded rapidly, from 810,000 acres in 1976, to 2,753,000 acres in 1978, and an estimated 4,140,000 acres for 1979 (3). Earlier harvest of sunflower has many advantages, (a) minimization of bird damage, (b) increased combine efficiency, and (c) earlier winter wheat planting (3). Sunflowers mature long before they are dry enough to combine. To prevent mildew damage or for temporary storage, seeds should be below 12% moisture content and for long term storage, seeds should be below 9.5% moisture (5). Paraquat has shown promise as a chemical harvest aid for sunflower (3,5).

Michigan grows 95% of the navy beans in the United States (24). In 1977, when Michigan had a wet Fall, approximately 70,000 acres of navy beans remained in the field (24). The use of a chemical harvest aid could have reduced this loss. Michigan State University has been researching the possibility of erect-type navy bean varieties which will allow for direct harvest. Adams (1) reported that these new varieties may require the use of chemical desiccation prior to harvest. In addition, Michigan bean growers will be increasing black turtle dry bean acreage in 1980. This variety of bean has problems of pod shattering and diseases at harvest (6). Chemical harvest aids reduced pod shattering in small seeded legumes (22), and reduced disease damage for potatoes (12). In Michigan, the greatest amount of chemical harvest aids are used for desiccating potato vines (28).

Chapter 2

Potential Chemical Harvest Aids for Navy Bean (*Phaseolus vulgaris*)

Abstract

At present, no chemical harvest aids are registered for use on navy bean (*Phaseolus vulgaris* L.) in Michigan, although prevailing weather conditions would frequently favor their use. Greenhouse and field experiments were initiated to evaluate four contact herbicides as potential chemical harvest aids on navy bean. In the greenhouse ametryn (2-ethylamino)-4(isopropylamino)-6-(methylthio)-*s*-triazine) at 1.1 and 2.2 kg/ha, dinoseb (2-(1-methylpropyl)-4,6-dinitrophenol) at 0.8 and 1.7 kg/ha, endothall (7-oxabicyclo(2,2,1)heptane-2,3-dicarboxylic acid) at 0.6 and 1.0 kg/ha, and paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) at 0.6 and 1.1 kg/ha were applied to navy bean plants and evaluated as desiccants seven days later. Variuos ammonium salts and ethephon (2-chloroethyl) phosphonic acid) were evaluated as adjuvants to increase efficacy in combination with the four contact herbicides. Ametryn at 1.1 kg/ha, paraquat at 0.6 kg/ha, dinoseb at 1.4 kg/ha, and endothall at 0.6 kg/ha were applied to navy bean in a field study. Ammonium sulfate, as a tank mix additive, at 9.0 kg/ha was compared to herbicides alone or in combination with crop oil or X-77 non-ionic surfactant (alkylaryl polyethylene glycol and free fatty acids). Paraquat was the most effective desiccant or harvest aid on navy bean. Ammonium sulfate at 9.0 kg/ha increased the efficacy of paraquat in both the greenhouse and in the field. Field studies

indicated that this combination had no adverse effects on navy bean germination or seed dry weight.

Introduction

A chemical harvest aid is an agricultural chemical which desiccates or defoiliates existing vegetation to facilitate an early or more timely harvest of a crop. The need for chemical crop desiccation is enhanced by prolonged wet periods in the Fall prior to harvest.

Michigan is the largest producer of navy bean in the United States (9). Currently, no registrations exist for the use of chemical harvest aids for this crop. However, in 1977 when Michigan had a wet Fall, approximately 28,000 ha of navy bean were not harvested (9). A chemical harvest aid could have reduced this loss.

Ametryn, dinoseb, endothall, and paraquat are all contact herbicides that causes localized injury to plant tissue where contact occurs (12). Paraquat has received a state label (24c) registration as a harvest aid on soybean (*Glycine max* (L.) Merr.) (3). Paraquat has also been used to accelerate drying in sunflower (*Helianthus annuus* L.) (3). The herbicide paraquat has been tested for accelerated drying of soybean and sunflower and has a restricted label use for potato (*Solanum tuberosum* L.) vine killing (6).

Ammonium sulfate, ammonium thiocyanate, and ethephon may increase absorption of herbicides. Ammonium thiocyanate increased amitrole (3-amino-*s*-triazole) translocation in quackgrass (*Agropyron repens* L.) (7). Ammonium sulfate increased absorption of ^{14}C bentazon

(3-isopropyl-1*H*-2,1,3 benzothiadiazin-(4)-3*H*-one 2,2-dioxide) and ^{14}C glyphosate (N-phosphonomethyl)glycine) on yellow nutsedge (*Cyperus esculentus* L.) (10). Ethephon increased absorption and basipetal movement of ^{14}C glyphosate in yellow nutsedge (10).

Ammonium ions prevent phosphorylation and increase rate of electron flow from plastoquinone to photosystem I (8). Paraquat removes electrons from the electron transport system of photosystem I, thus inhibiting the reduction of NADP to NADPH (2). Calderbank (5) reported that hydrogen peroxide produced during reoxidation of the bipyridylium-free radical is the toxicant causing rapid injury of the plant; also reactive hydroxyl radicals may be involved. Ammonium ions may interact with herbicides that inhibit electron flow.

The purpose of this research was to evaluate several potential chemical harvest aids and to determine efficacy of various ammonium salts and ethephon as additives for increasing efficacy on navy bean.

Materials and Methods

'Seafarer' navy bean seeds were planted in greenhouse soil at the rate of five sseds per 946-ml cup and after germination were thinned to two plants per cup. Water was added to the soil daily with a 20-20-20 N-P-K Peters fertilizer solution at 100 ppm. The plants were grown without supplemental lighting under a 14 h day until the third trifoliolate leaf was completely expanded, the stage selected for the treatment.

Ametryn was applied at 1.1 and 2.2 kg/ha, dinoseb at 0.8 and 1.7 kg/ha, endothall at 0.6 and 1.0 kg/ha, and paraquat at 0.6 and 1.1

kg/ha. All herbicide concentrations were applied at the rate of 347 L/ha. Crop oil 'Herbimax' was applied in combination with herbicides at 2.3 and 4.6 L/ha. 'X-77' [1], a non-ionic surfactant was applied in combination with herbicides at 1.2 and 2.4 L/ha. Ethephon and all ammonium salts were applied in combination with herbicides at 4.5 and 9.0 kg/ha. Seven days after herbicide treatment, plants were rated for visual injury, and fresh weights and dry weights determined. The data presented are the means of two experiments with four replications per experiment.

A field study to evaluate the results obtained from the greenhouse study was initiated on the Cliff Roggenbuck farm near Port Hope, Michigan. 'Seafarer' navy bean were planted in four 76 cm by 18.3 m rows per treatment. The experimental design was a randomized complete block with four replications.

Ametryn at 1.1 kg/ha, dinoseb at 1.4 kg/ha, and endothall at 0.6 kg/ha, and paraquat at 0.6 kg/ha were applied in 208 L/ha aqueous spray. 'Herbimax' crop oil was applied in combination with herbicide at 2.3 L/ha. 'X-77' non-ionic surfacant was applied with paraquat at 1.2 L/ha. Ammonium sulfate was applied in combination with herbicides at 9.0 kg/ha. Seven days after treatment, the center two rows were harvested in each plot. Desiccation was rated visually and 400 pods were collected at random from each plot. The fresh weight of 100 pods was determined after the seeds were removed. Samples of 100 seeds were also weighed to determine harvest aid influence on seed weight.

[1] Alkylaryl polyethylene glycol and free fatty acids

Pods and seeds were dryed to 13% moisture and dry weights were determined. Percent moisture content of both seeds and pods were calculated. Seed germination was determined for 100 seeds of each plot by Michigan Crop Improvement Association.

Results and Discussion

Ametryn was only moderately effective as a chemical harvest aid on navy bean (Table 1). The addition of ammonium phosphate, ammonium thiocyanate, or ethephon only slightly increased the efficacy of ametryn. Inclusion of a crop oil with ethephon plus ametryn combination gave a significant increase in desiccation of navy bean. Increasing the rate of crop oil application from 2.3 to 4.6 L/ha applied solely with ametryn offered no greater efficacy than the 2.3 L/ha rate. The three-way combination of ammonium sulfate at 4.5 and 9.0 kg/ha and crop oil at 2.3 L/ha with ametryn markedly increased desiccation of the navy bean plants and was the most effective ametryn treatment (Table 1). Averaged over all additive treatments, the 1.1 kg/ha rate of ametryn application was not significantly different from the 2.2 kg/ha rate.

In contrast, the efficacy of endothall averaged over all additive treatments increased as the application rate increased from 0.6 kg/ha to 1.0 kg/ha. The addition of crop oil concentrate to the spray solution only slightly increased endothall efficacy (Table 2). All of the additives except ammonium thiocyanate providely increased endothall efficacy. Ammonium sulfate appeared to be slightly more effective across a number of treatments than the other additives (Table 2).

Averaged over all additive treatments, the 1.7 kg/ha rate of dinoseb application was significantly more effective than the 0.8 kg/ha rate as a chemical harvest aid for navy bean. Without additives, dinoseb at both rates caused little or no desiccation of the navy bean (Tables 4 and 5). The additives ranked as follows in ascending order of effectiveness in increasing dinoseb activity: ammonium phosphate, ammonium sulfate, ammonium thiocyanate, and ethephon. All were more effective than dinoseb plus only crop oil. The three-way combination including crop oil was generally more effective than the two-way combination of dinoseb plus ammonium salt or ethephon (Table 3).

Examination of the three-way combination at specific rates of dinoseb applications in combination with ethephon plus crop oil provided no added advantage to the higher 1.7 kg/ha dinoseb application rate (Table 4), whereas in the three-way combination of crop oil plus ammonium sulfate plus dinoseb, increasing the dinoseb rate from 0.8 kg/ha to 1.7 kg/ha also increased desiccation of navy bean (Table 5).

Averaged over all additive treatments, the 1.1 kg/ha rate of paraquat application was significantly more effective than the 0.6 kg/ha rate as a chemical harvest aid for navy bean. Ammonium phosphate, ammonium thiocyanate, and ethephon, applied at 4.5 and 9.0 kg/ha in combination with paraquat, failed to increase the desiccation of navy bean plants by paraquat alone (Table 6). X-77 non-ionic surfactant, applied at 1.2 and 2.4 L/ha in combination with paraquat, significantly increased navy bean desiccation. However, there was no difference between the X-77 rates. Ammonium sulfate applied at 4.5 and 9.0 kg/ha markedly increased efficacy of paraquat over all other combinations. A triple combination of ammonium sulfate at 4.5 and 9.0 kg/ha with 1.2 L/ha of X-77 and paraquat reduced the ammonium sulfate enhancement (Table 6).

In the greenhouse study, increasing the paraquat rate from 0.6 to 1.1 kg/ha in combination with ammonium sulfate also increased desiccation to the highest level observed in this study (Table 7).

In a field study to evaluate the results from the greenhouse study under field conditions, dinoseb at 1.4 kg/ha proved to be ineffective as a chemical harvest aid (Table 8). The addition of X-77 to paraquat or crop oil to ametryn, dinoseb and endothall all provided for greater desiccation than the herbicides alone. However, the addition of ammonium sulfate to paraquat, ametryn, and dinoseb provided much greater enhancement of desiccation than the X-77 or crop oil (Table 8). This is exemplified in the reduction of the percent moisture content of the navy bean pods from 47% in the control to 28% by 0.6 kg/ha paraquat, 24% by 0.6 kg/ha paraquat plus X-77, to 13% by 0.6 kg/ha paraquat plus 9.0 kg/ha ammonium sulfate (Table 8).

Ammonium sulfate at 9.0 kg/ha in combination with paraquat at 0.6 k/gha, dinoseb at 1.4 kg/ha, endothall at 0.6 kg/ha and ametryn at 1.1 kg/ha did not alter the percent germination compared to the control. Ammonium sulfate at 9.0 kg/ha in combination with ametryn at 1.1 kg/ha and endothall at 0.6 kg/ha resulted in a decrease in dry weight of 100 seeds (Table 9). Ammonium sulfate at 9.0 kg/ha in combination with paraquat at 0.6 kg/ha and dinoseb at 1.4 kg/ha did not significantly affect seed dry weight (Table 9).

Turner and Loader (11) reported ammonium salts did not enhance the activity of paraquat. However, their experiments were conducted on guava (*Psidium guajava* L.), poplar (*Populus euroamericana* L.) and privet (*Ligustrum ovalifolium* L.). Bovey and Diaz-Colon (4) reported that oil-soluble herbicides are more effective than paraquat on guava.

Ammonium salts have increased efficacy of many herbicides (11). Ammonium sulfate has particular advantages because of its low cost and low mammalian toxicity.

In summary, paraquat at 0.6 or 1.1 kg/ha in combination with ammonium sulfate at 9.0 kg/ha resulted in the most complete desiccation of navy bean plants. Field studies indicated that paraquat at 0.6 kg/ha in combination with 9.0 kg/ha of ammonium sulfate had no adverse effects on navy bean germination or seed dry weight.

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Table 1. Percent moisture content and visual injury of navy bean plants following postemergence application of ametryn averaged over rates of 0.0, 1.1, and 2.2 kg/ha applied with ammonium salts, ethephon, or crop oil.

Treatment (Additive)	Additive Rate (kg/ha)	Oil Rate (L/ha)	Visual Injury Rating (After 7 Days)[a]	Moisture Content (%)
Control	---	---	0.0 i[b]	88 a
Ammonium phosphate	0	0	6.5 fgh	76 bcde
	4.5	0	7.5 de	75 cdef
	9.0	0	7.0 efg	76 bcde
	4.5	2.3	7.0 efg	74 def
	9.0	2.3	6.5 fgh	76 bcde
Ammonium sulfate	0	0	6.5 fgh	76 bcde
	4.5	0	8.2 bcd	73 efg
	9.0	0	8.8 bc	71 g
	4.5	2.3	9.8 a	66 h
	9.0	2.3	9.8 a	66 h
Ammonium thiocyanate	0	0	6.5 fgh	76 bcde
	4.5	0	5.6 h	79 b
	9.0	0	7.9 cde	73 efg
	4.5	2.3	6.4 gh	78 bc
	9.0	2.3	8.5 bc	73 efg
Ethephon	0	0	6.5 fgh	76 bcde
	4.5	0	7.2 efg	76 bcde
	9.0	0	7.4 def	74 def
	4.5	2.3	6.0 h	77 bcd
	9.0	2.3	8.8 bc	71 g
Crop Oil	0	0	6.5 fgh	76 bcde
	0	2.3	8.9 b	71 g
	0	4.6	8.8 bc	72 g

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within colums for a given additive with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table 2. Percent moisture content and visual injury of navy bean plants following postemergence application of endothall averaged over rates of 0.0, 0.6, and 1.0 kg/ha applied with ammonium salts, ethephon, or crop oil.

Treatment (Additive)	Additive Rate (kg/ha)	Crop Oil Rate (L/ha)	Visual Injury Rating (After 7 Days)[a]	Moisture Content (%)
Control	---	---	0.0 i[b]	82 a
Ammonium phosphate	0	0	8.4 def	69 bcd
	4.5	0	9.8 ab	62 gh
	9.0	0	7.8 egfh	70 bcd
	4.5	2.3	8.6 de	70 bcd
	9.0	2.3	9.0 bcd	64 efg
Ammonium sulfate	0	0	8.4 def	69 bcd
	4.5	0	8.9 cd	67 de
	9.0	0	9.4 abc	64 efg
	4.5	2.3	9.8 ab	66 ef
	9.0	2.3	10.0 a	61 h
Ammonium thiocyanate	0	0	8.4 def	69 bcd
	4.5	0	7.0 h	74 b
	9.0	0	7.4 gh	72 bc
	4.5	2.3	7.8 efgh	72 bc
	9.0	2.3	8.9 cd	68 cde
Ethephon	0	0	8.4 def	69 bcd
	4.5	0	8.8 cd	66 ef
	9.0	0	9.5 abc	64 efg
	4.5	2.3	8.5 de	67 de
	9.0	2.3	8.9 cd	69 bcd
Crop Oil	0	0	8.4 def	69 bcd
	0	2.3	7.6 fgh	72 bc
	0	4.6	7.5 gh	71 bc

[a] Ratings were 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns for a given additive with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table 3. Percent moisture content and visual injury of navy bean plants following postemergence application of dinoseb averaged over rates of 0.0, 0.8, and 1.7 kg/ha applied with ammonium salts, ethephon, or crop oil.

Treatment (Additive)	Additive Rate (kg/ha)	Crop Oil Rate (L/ha)	Visual Injury Rating (After 7 Days)[a]	Moisture Content (%)
Control	---	---	0.0 j[b]	83 a
Ammonium phosphate	0	0	0.2 j	83 a
	4.5	0	5.5 i	77 c
	9.0	0	7.4 ef	74 d
	4.5	2.3	6.8 fg	74 d
	9.0	2.3	7.5 ef	74 d
Ammonium sulfate	0	0	0.2 j	83 a
	4.5	0	7.4 ef	74 d
	9.0	0	5.8 hi	76 c
	4.5	2.3	9.0 bc	68 f
	9.0	2.3	8.8 bc	69 e
Ammonium thiocyanate	0	0	0.2 j	83 a
	4.5	0	6.4 gh	76 c
	9.0	0	8.9 bc	69 e
	4.5	2.3	9.0 bc	69 e
	9.0	2.3	9.5 ab	65 h
Ethephon	0	0	0.2 j	83 a
	4.5	0	8.0 de	70 e
	9.0	0	8.6 bc	66 g
	4.5	2.3	9.5 ab	66 g
	9.0	2.3	10.0 a	62 i
Crop Oil	0	0	0.2 j	83 a
	0	2.3	5.5 i	78 b
	0	4.6	5.2 i	79 b

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns for a given additive with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table 4. Percent moisture content and visual injury of navy bean plants following postemergence application of dinoseb with ethephon or crop oil.

Dinoseb Rate (kg/ha)	Ethephon Rate (kg/ha)	Crop Oil Rate (L/ha)	Visual Injury Rating (After 7 Days)[a]	Moisture Content (%)
0.0	0.0	0.0	0.0 e[b]	83 ab
0.0	4.5	0.0	2.0 d	80 bc
0.0	9.0	0.0	2.5 d	79 c
0.0	0.0	2.3	0.0 e	84 a
0.0	0.0	4.6	0.0 e	84 a
0.8	0.0	0.0	0.5 e	82 ab
0.8	4.5	0.0	7.0 b	70 e
0.8	9.0	0.0	7.2 b	70 e
0.8	0.0	2.3	4.2 c	77 c
0.8	0.0	4.6	4.0 c	78 c
0.8	4.5	2.3	9.0 a	62 f
0.8	9.0	2.3	10.0 a	48 i
1.7	0.0	0.0	0.0 e	84 a
1.7	4.5	0.0	9.0 a	60 f
1.7	9.0	0.0	10.0 a	51 h
1.7	0.0	2.3	6.8 b	72 d
1.7	0.0	4.6	6.5 b	73 d
1.7	4.5	2.3	10.0 a	54 g
1.7	9.0	2.3	10.0 a	54 g

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns for a given additive with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table 5. Percent moisture content and visual injury of navy bean plants following postemergence application of dinoseb with ammonium sulfate or crop oil.

Dinoseb Rate (kg/ha)	Ammonium sulfate Rate (kg/ha)	Crop Oil Rate (L/ha)	Visual Injury Rating (After 7 Days)[a]	Moisture Content (%)
0.0	0.0	0.0	0.0 h[b]	83 ab
0.0	4.5	0.0	0.0 h	84 a
0.0	9.0	0.0	0.0 h	85 a
0.0	0.0	2.3	0.0 h	84 a
0.0	0.0	4.6	0.0 h	84 a
0.8	0.0	0.0	0.5 h	82 bc
0.8	4.5	0.0	6.8 e	72 e
0.8	9.0	0.0	3.2 g	80 c
0.8	0.0	2.3	4.2 f	77 d
0.8	0.0	4.6	4.0 f	78 d
0.8	4.5	2.3	8.0 d	67 f
0.8	9.0	2.3	8.5 cd	64 g
1.7	0.0	0.0	0.0 h	84 a
1.7	4.5	0.0	8.0 d	66 f
1.7	9.0	0.0	9.0 bc	63 g
1.7	0.0	2.3	6.8 e	72 e
1.7	0.0	4.6	6.5 e	73 e
1.7	4.5	2.3	10.0 a	54 i
1.7	9.0	2.3	9.5 ab	60 h

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns for a given additive with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table 6. Percent moisture content and visual injury of navy bean plants following postemergence application of paraquat averaged over rates of 0.0, 0.6, and 1.1 kg/ha applied with ammonium salts, ethephon, or crop oil.

Treatment (Additive)	Additive Rate (kg/ha)	X-77 Rate (L/ha)	Visual Injury Rating (After 7 Days)[a]	Moisture Content (%)
Control	---	---	0.0 j[b]	88 a
Ammonium phosphate	0	0	7.8 b	72 g
	4.5	0	3.8 ef	80 bcde
	9.0	0	4.0 e	80 bcde
	4.5	1.2	4.0 e	79 cde
	9.0	1.2	2.0 hi	83 b
Ammonium sulfate	0	0	7.8 b	72 g
	4.5	0	9.2 a	66 h
	9.0	0	10.0 a	54 i
	4.5	1.2	6.9 c	76 f
	9.0	1.2	4.5 e	77 ef
Ammonium thiocyanate	0	0	7.8 b	72 g
	4.5	0	6.5 cd	81 bcd
	9.0	0	4.0 e	77 ef
	4.5	1.2	6.2 cd	78 de
	9.0	1.2	1.8 i	83 b
Ethephon	0	0	7.8 b	72 g
	4.5	0	6.9 c	76 f
	9.0	0	5.8 d	77 ef
	4.5	1.2	3.1 fg	82 bc
	9.0	1.2	2.8 gh	82 bc
X-77	0	0	7.8 b	72 g
	0	1.2	8.0 b	70 g
	0	2.4	8.2 b	69 g

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns for a given additive with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table 7. Percent moisture content and visual injury of navy bean plants following postemergence application of paraquat with ammonium sulfate or X-77.

Paraquat Rate (kg/ha)	Ammonium sulfate Rate (kg/ha)	X-77 Rate (L/ha)	Visual Injury Rating (After 7 days)[a]	Moisture Content (%)
0.0	0.0	0.0	0.0 i[b]	88 a
0.0	4.5	0.0	0.0 i	87 a
0.0	9.0	0.0	0.0 i	87 a
0.0	0.0	1.2	0.0 i	89 a
0.0	0.0	2.4	0.0 i	88 a
0.6	0.0	0.0	7.4 ef	68 cde
0.6	4.5	0.0	8.5 bc	58 fg
0.6	9.0	0.0	10.0 a	44 i
0.6	0.0	1.2	7.0 f	69 cd
0.6	0.0	2.4	7.5 ef	70 cd
0.6	4.5	1.2	6.0 g	74 c
0.6	9.0	1.2	1.0 h	82 b
1.1	0.0	0.0	8.2 cd	60 f
1.1	4.5	0.0	9.0 b	53 gh
1.1	9.0	0.0	10.0 a	33 j
1.1	0.0	1.2	9.0 b	50 h
1.1	0.0	2.4	9.0 b	51 h
1.1	4.5	1.2	7.8 de	67 de
1.1	9.0	1.2	8.0 cde	62 ef

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns for a given additive with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table 8. Percent moisture content and visual injury of navy bean pods and seeds following postemergence application of paraquat, dinoseb, endothall, and ametryn with additives ammonium sulfate, X-77, or crop oil.

Treatment	Rate (kg/ha)	Visual Injury Rating (After 7 Days)[a]	Pod Moisture (%)	Seed Moisture (%)
Control	0.0	0.5 f[b]	47 ab	31 c
Paraquat	0.6	7.0 c	28 e	26 de
Paraquat + X-77	0.6 + 1.2 L/ha	8.5 b	24 f	20 gh
Paraquat + ammonium sulfate	0.6 + 9.0	10.0 a	13 h	15 i
Dinoseb	1.4	2.5 e	45 b	35 b
Dinoseb + oil	1.4 + 2.3 L/ha	7.0 c	28 e	24 ef
Dinoseb + ammonium sulfate	1.4 + 9.0	9.8 a	18 g	17 hi
Endothall	0.6	6.5 c	34 cd	31 c
Endothall + oil	0.6 + 2.3 L/ha	8.5 b	23 f	17 hi
Endothall + ammonium sulfate	0.6 + 9.0	7.2 c	32 d	26 de
Ametryn	1.1	4.0 d	38 c	28 cd
Ametryn + oil	1.1 + 2.3 L/ha	4.5 d	35 cd	24 ef
Ametryn + ammonium sulfate	1.1 + 9.0	8.0 b	27 ef	22 fg
X-77	1.2 L/ha	0.5 f	49 a	40 a
Oil	2.3 L/ha	2.0 e	35 cd	28 cd
Ammonium sulfate	9.0	2.0 e	34 cd	26 de

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table 9. Percent germination and seed dry weight of navy bean plants following postemergence application of paraquat, dinoseb, endothall, and ametryn with additives ammonium sulfate, X-77, or crop oil.

Treatment	Rate (kg/ha)	Germination (%)	Dry Weight (gm/100 seeds)
Control	0.0	96 a[a]	18.6 ab
Paraquat	0.6	93 abc	16.6 d
Paraquat + X-77	0.6 + 1.2 L/ha	98 a	17.6 abc
Paraquat + ammonium sulfate	0.6 + 9.0	96 a	17.5 abc
Dinoseb	1.4	88 c	17.8 abc
Dinoseb + oil	1.4 + 2.3 L/ha	90 bc	17.7 abc
Dinoseb + ammoniun sulfate	1.4 + 9.0	94 abc	19.2 a
Endothall	0.6	92 abc	17.3 bc
Endothall + oil	0.6 + 2.3 L/ha	93 abc	17.0 cd
Endothall + ammonium sulfate	0.6 + 9.0	95 ab	17.4 bc
Ametryn	1.1	90 bc	18.5 ab
Ametryn + oil	1.1 + 2.3 L/ha	94 abc	17.8 abc
Ametryn + ammonium sulfate	1.1 + 9.0	96 a	17.0 cd
X-77	1.2 L/ha	92 abc	18.8 a
Oil	2.3 L/ha	95 ab	18.4 ab
Ammonium sulfate	9.0	96 a	18.3 ab

[a] Means within columns with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Chapter 3

The Use of Additives to Increase Efficacy of Dinoseb for Potato (*Solanum tuberosum*) Vine Desiccation

Abstract

In Michigan, chemical vine desiccation is an important management practice for late season potatoes (*Solanum tuberosum* L.). A number of chemicals are registered, however, approximately 67% of the growers apply dinoseb (2-*sec*-butyl-4,6-dinitrophenol) (4). Greenhouse and field experiments were initiated to evaluate the potential of ammonium salts and ethephon ((2-chloroethyl) phosphonic acid) to increase the efficacy of chemical harvest aids on potato vines.

Dinoseb and endothall (7-oxabicyclo(2,2,1)heptane-2,3-diacarboxylic acid) were evaluated in combination with additives. All treatments with endothall applied at 0.6 kg/ha resulted in unsatisfactory desiccation to potato vines in the greenhouse. Ethephon and ammonium sulfate increased efficacy of dinoseb in greenhouse and field studies. The combination of ammonium sulfate at 9 kg/ha plus 2.3 L/ha of crop oil plus 1.4 kg/ha dinoseb gave equivalent potato vine kill to 2.8 kg/ha dinoseb plus 2.3 L/ha crop oil.

Introduction

Chemical potato vine killing has developed as an essential commercial practice for long season variety potatoes. It is practiced mainly for five reasons: a) to reduce the spread of virus diseases in seed potato fields, b) to control late blight tuber rot, c) to allow harvesting the crop before freezing weather, d) to control tuber size, e) to improve skin maturity (2,3). In Michigan, a number of chemicals are registered for potato vine desiccation, however, apporximately 67% of the growers apply dinoseb (4).

Phytobland oils and organic surfactants are commonly used as spray additives for chemical harvest aid contact herbicides. With cultivars such as 'Sebago', however, potato vine killing often requires a split application.

Inorganic salts as additives have been shown to increase efficacy of herbicides, such as bentazon (3-isopropyl-1*H*-2,1,3 benzothiadiazin-(4)-3*H*-one 2,2 dioxide) and glyphosate (N-(phosphonomethyl) glycine) for yellow nutsedge (*Cyperus esculentus* L.) control (6). Ammonium sulfate has increased efficacy of dinitro phenol herbicide, DNOC (4,6-dinitro-*o*-cresol), and endothall (1,5).

The objective of this research was to evaluate potential ammonium salts and ethephon as additives to increase efficacy of dinoseb and endothall for potato vine killing.

Materials and Methods

'Superior' potatoes were grown in the greenhouse at 25 $\pm$ 2c without supplemental fluorescent lighting. Potato seed pieces were planted in 946-ml cups. After germination, vines were thinned to two stalks per cup. New growth was continuously cut to keep only two vines per pot. The potato plants were watered daily with 20-20-20 (N-P-K) Peters fertilizer solution at 100 ppm to insure vigorous vine growth. Careful watering prevented nutrient solution from coming in contact with foliage. Potato vines were grown to 20 cm tall prior to treatment.

Dinoseb at 0.8 and 1.7 kg/ha and endothall at 0.6 kg/ha were applied to vigorous 20 cm tall vines. All herbicide concentrations were applied at a rate of 347 L/ha. Crop oil 'Herbimax' was applied in combination with herbicides at 2.3 and 4.6 L/ha. Ethephon and all ammonium salts were applied in combination with herbicides at 4.5 and 9.0 kg/ha. Ten days after herbicide treatments, potato vines were rated for visual injury; fresh weight and dry weights were determined. The data presented are the means of two experiments with four replications per experiment.

To evaluate greenhouse results under field conditions, experimental treatments in the field were applied to 'Sebago' potato vines at Wayne Gruesbeck's farm in Eaton Rapids, Michigan. Potatoes were planted May 14, 1979. Plots were three rows 86.4 cm wide and 4.6 m long with a tuber spacing of 17.8 cm. A randomized complete block design with four replications was used. Treatments were applied with handheld CO_2 pressurized sprayer applying 254 L/ha at 2.8 kg/cm^2.

Dinoseb was applied at 1.4, 2.8, and 5.6 kg/ha to vigorous growing vines on September 24, 1979. Ammonium sulfate was applied at 9.0 kg/ha.

Crop oil was applied at 2.3 L/ha. Ten days after application, vines were rated for visual injury. The center row of each plot was harvested by hand. Tuber skinning and vascular discoloration were recorded from 25 randomly sampled tubers of each replication. Tuber discoloration data was determined by cutting 25 tubers, once at harvest and again 30 days after harvest.

To evaluate greenhouse results under field conditions, experimental treatments in the field were applied to 'Monona' potato vines at the Montcalm Experimental Farm in Entrican, Michigan. Potatoes were planted May 16, 1979. Plot size was three rows 86.4 cm wide, 4.6 m long and a 25.4 cm tuber spacing. Each plot was arranged in randomized complete block design with four replications. Treatments were applied with a handheld sprayer applying 254 L/ha at 2.1 kg/cm^2.

Dinoseb was applied at 1.4 kg/ha to vigorous growing vines on August 13, 1979. Ammonium sulfate and ethephon were applied at 9.0 kg/ha. Crop oil was applied at 2.3 L/ha. Ten days after application, August 23, 1979, visual injury ratings were taken. Potatoes were harvested August 24, 1979, by a one-row mechanical harvester developed at Michigan State University. The center row of each plot was harvested. Specific gravity, tuber skinning, and tuber discoloration were recorded from random samples of tubers. Tuber discoloration data represents averages of two separate cuttings of 25 tubers, one at harvest and one 30 days after harvest.

Results and Discussion

In the greenhouse, endothall at 0.6 kg/ha was not an effective desiccant on 'Superior' potato vines (Table 1). Ammonium phosphate, ammonium thiocyanate, and crop oil in combination with endothall did not satisfactorily increase desiccation of potato vines (Table 1). Ammonium sulfate applied at 9.0 kg/ha without added crop oil increased efficacy of endothall to some degree. Ethephon at 4.5 kg/ha plus crop oil at 2.3 L/ha caused the greatest increase in efficacy of endothall, however, desiccation was still poor.

Dinoseb at 1.7 kg/ha evaluated over all additive treatments significantly increased potato vine desiccation more than 0.8 kg/ha rate. Ammonium phosphate or ammonium thiocyanate alone or plus crop oil in combination with dinoseb resulted in a moderate increase in desiccation to potato vines compared to dinoseb alone (Table 2). Ethephon or ammonium sulfate at 4.5 and 9.0 kg/ha in combination with crop oil at 2.3 L/ha markedly increased the efficacy of dinoseb (Table 2).

Examination of several rates of dinoseb application as shown in Table 3 indicated that crop oil at 2.3 and 4.6 L/ha enhanced the activity of dinoseb at 1.7 kg/ha. Ethephon at 9.0 kg/ha markedly increased efficacy of dinoseb at both 0.8 and 1.7 kg/ha. Maximum desiccation to potato vines resulted when ethephon at 9.0 kg/ha and crop oil at 2.3 L/ha were combined with dinoseb at 0.8 and 1.7 kg/ha.

Ammonium sulfate at 9.0 kg/ha resulted in enhancement of dinoseb efficacy at 1.7 kg/ha (Table 4). Ammonium sulfate at 9.0 kg/ha in combination with crop oil at 2.3 L/ha markedly increased efficacy of dinoseb at both 0.8 and 1.7 kg/ha.

Similarly in field studies as shown in Table 5, the addition of 9.0 kg/ha of ammonium sulfate to dinoseb plus crop oil at 2.3 L/ha increased the efficacy of dinoseb at 1.4 kg/ha rate to that observed at the 2.8 kg/ha rate plus crop oil without ammonium sulfate. Dinoseb alone at 1.4 and 2.8 kg/ha resulted in unsatisfactory vine desiccation of 'Sebago' potatoes. Crop oil at 2.3 L/ha increased efficacy of dinoseb at 2.8 kg/ha. The three-way combination of ammonium sulfate at 9.0 kg/ha, crop oil at 2.3 L/ha and dinoseb at 1.4 and 2.8 kg/ha resulted in no tuber skinning or tuber discoloration. Ammonium sulfate at 9.0 kg/ha, crop oil at 2.3 L/ha in combination with dinoseb at 5.6 kg/ha completely desiccated potato vines, however, some tuber discoloration resulted.

In another field study, dinoseb alone at 1.4 kg/ha resulted in inadequate vine kill of 'Monona' potatoes (Table 6). Crop oil at 2.3 L/ha did not increase dinoseb efficacy at 1.4 kg/ha. Ammonium sulfate at 9.0 kg/ha plus crop oil at 2.34 L/ha markedly increased efficacy of dinoseb at 1.4 kg/ha without detrimental tuber skinning or tuber discoloration (Table 6). Combinations of ethephon at 9.0 kg/ha plus crop oil at 2.3 L/ha with dinoseb at 1.4 kg/ha also resulted in markedly enhancement of dinoseb activity. However, this three-way combination resulted in tuber skinning, thus reducing tuber quality.

In this study, ammonium sulfate showed greatest potential as an additive to increase efficacy of dinoseb. Greenhouse and field studies indicate a three-way combination of ammonium sulfate plus crop oil plus dinoseb can increase desiccation to potato vines without detrimental effects on tuber quality. The combination of 9.0 kg/ha ammonium sulfate plus crop oil at 2.3 L/ha plus 1.4 kg/ha dinoseb gave equivalent potato vine kill on 'Sebago' to 2.8 kg/ha dinoseb plus 2.3 L/ha crop oil.

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Table 1. Percent shoot moisture content and visual injury of 20 cm tall 'Superior' potato vines averaged over rates of 0.0 and 0.6 kg/ha postemergence application of endothall with ammonium salts, ethephon and crop oil.

Treatment (Additive)	Additive Rate (kg/ha)	Crop Oil Rate (L/ha)	Visual Injury Rating[a] (After 10 Days)	Shoot Moisture Content[b] (%)
Control	---	---	0.0 f	91 ab
Ammonium phosphate	0	0	0.0 f	91 ab
	4.5	0	0.0 f	91 ab
	9.0	0	4.0 c	88 bc
	4.5	2.3	0.0 f	91 ab
	9.0	2.3	4.0 c	88 bc
Ammonium sulfate	0	0	0.0 f	91 ab
	4.5	0	2.0 e	90 ab
	9.0	0	5.0 b	88 bc
	4.5	2.3	0.0 f	91 ab
	9.0	2.3	0.0 f	90 ab
Ammonium thiocyanate	0	0	0.0 f	91 ab
	4.5	0	0.0 f	92 a
	9.0	0	5.5 b	89 ab
	4.5	2.3	0.0 f	91 ab
	9.0	2.3	3.0 d	89 ab
Ethephon	0	0	0.0 f	91 ab
	4.5	0	5.8 b	88 bc
	9.0	0	2.0 e	91 ab
	4.5	2.3	7.5 a	86 c
	9.0	2.3	4.2 c	89 ab
Crop Oil	0	0	0.0 f	91 ab
	0	2.3	0.5 f	90 ab
	0	4.6	0.5 f	91 ab

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table 2. Percent shoot moisture content and visual injury of 20 cm tall 'Superior' potato vines averaged over rates of 0.0, 0.8 and 1.7 kg/ha postemergence applications of dinoseb with ammonium salts, ethephon, and crop oil.

Treatment (Additive)	Additive Rate (kg/ha)	Crop Oil Rate (L/ha)	Visual Injury Rating[a] (After 10 Days)	Shoot Moisture Content[b] (%)
Control	---	---	0.0 i	90 a
Ammonium phosphate	0	0	2.0 h	88 a
	4.5	0	5.8 hf	82 b
	9.0	0	6.2 ef	80 bc
	4.5	2.3	6.8 cde	78 de
	9.0	2.3	9.2 a	68 g
Ammonium sulfate	0	0	2.0 h	88 a
	4.5	0	5.8 f	82 b
	9.0	0	7.6 bc	76 ef
	4.5	2.3	9.4 a	59 h
	9.0	2.3	10.0 a	45 i
Ammonium thiocyanate	0	0	2.0 h	88 a
	4.5	0	5.8 f	82 b
	9.0	0	7.8 b	74 f
	4.5	2.3	6.4 def	79 cd
	9.0	2.3	6.6 def	79 cd
Ethephon	0	0	2.0 h	88 a
	4.5	0	7.2 bcd	76 ef
	9.0	0	9.4 a	67 g
	4.5	2.3	9.5 a	57 h
	9.0	2.3	10.0 a	44 i
Crop Oil	0	0	2.0 h	88 a
	0	2.3	4.5 g	82 b
	0	4.6	4.0 g	82 b

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table 3. Percent shoot moisture content and visual injury of 20 cm tall 'Superior' potato vines treated with postemergence application of dinoseb with ethephon and crop oil.

Dinoseb Rate (kg/ha)	Ethephon Rate (kg/ha)	Concentrated oil (L/ha)	Visual Injury Rating[a] (After 10 Days)	Shoot Moisture Content[b] (%)
0.0	0.0	0.0	0.0 i	90 a
0.0	4.5	0.0	0.0 i	89 a
0.0	9.0	0.0	0.0 i	91 a
0.0	0.0	2.3	0.0 i	89 a
0.0	0.0	4.6	0.0 i	89 a
0.8	0.0	0.0	0.0 i	90 a
0.8	4.5	0.0	6.0 f	76 c
0.8	9.0	0.0	9.2 bc	57 ef
0.8	0.0	2.3	1.0 h	88 ab
0.8	0.0	4.6	0.0 i	89 a
0.8	4.5	2.3	9.0 c	60 e
0.8	9.0	2.3	10.0 a	22 g
1.7	0.0	0.0	4.0 g	84 b
1.7	4.5	0.0	8.5 d	65 d
1.7	9.0	0.0	9.5 b	54 f
1.7	0.0	2.3	8.0 e	67 d
1.7	0.0	4.6	8.0 e	68 d
1.7	4.5	2.3	10.0 a	22 g
1.7	9.0	2.3	10.0 a	21 g

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table 4. Percent shoot moisture content and visual injury of 20 cm tall 'Superior' potato vines treated with postemergence application of dinoseb with ammonium sulfate and crop oil.

Dinoseb Rate (kg/ha)	Ammonium sulfate Rate (kg/ha)	Concentrated oil (L/ha)	Visual Injury Rating[a] (After 10 Days)	Shoot Moisture Content[b] (%)
0.0	0.0	0.0	0.0 g	90 a
0.0	4.5	0.0	0.0 g	90 a
0.0	9.0	0.0	0.0 g	90 a
0.0	0.0	2.3	0.0 g	89 a
0.0	0.0	4.6	0.0 g	89 a
0.8	0.0	0.0	0.0 g	90 a
0.8	4.5	0.0	4.2 e	84 ab
0.8	9.0	0.0	6.5 d	74 c
0.8	0.0	2.3	1.0 f	88 ab
0.8	0.0	4.6	0.0 g	89 a
0.8	4.5	2.3	8.8 b	62 e
0.8	9.0	2.3	10.0 a	22 f
1.7	0.0	0.0	4.0 e	84 ab
1.7	4.5	0.0	7.5 c	70 d
1.7	9.0	0.0	8.8 b	62 e
1.7	0.0	2.3	8.0 c	67 d
1.7	0.0	4.6	8.0 c	68 d
1.7	4.5	2.3	10.0 a	26 f
1.7	9.0	2.3	10.0 a	22 f

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table 5. Visual injury and tuber quality evaluated in the field when 'Sebago' potato vines were treated with postemergence applications of different rates of dinoseb with ammonium sulfate and crop oil.

Dinoseb Rate (kg/ha)	Ammonium sulfate Rate (kg/ha)	Crop oil (L/ha)	Visual Injury Rating[a] (After 10 Days)	Tuber Skinning (25 tubers)	Tuber Discoloration (25 tubers)
0.0	0.0	0.0	2.2 h[b]	1.0[c]	0.0[d]
0.0	9.0	0.0	4.3 g	0.0	0.0
1.4	0.0	0.0	6.0 f	0.0	0.0
1.4	0.0	2.3	7.0 e	0.0	0.0
1.4	9.0	0.0	7.2 e	0.0	0.0
1.4	9.0	2.3	9.0 bc	0.0	0.0
2.8	0.0	0.0	8.0 d	0.0	0.0
2.8	0.0	2.3	9.0 bc	9.0	0.0
2.8	9.0	0.0	8.8 c	0.0	0.0
2.8	9.0	2.3	9.0 bc	0.0	0.0
5.6	0.0	0.0	9.0 bc	0.0	0.2
5.6	0.0	2.3	9.5 ab	0.0	0.4
5.6	9.0	0.0	9.5 ab	0.0	0.3
5.6	9.0	2.3	10.0 a	0.0	0.4

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within column with similar letters are not signifantly different at the 1% level by Duncan's multiple range test.

[c] Ratings were on a 0 to 3 scale; 0 = no skinning, 1 = low skinning, 2 = moderate, 3 = severe.

[d] Ratings were on a 0 to 3 scale; 0 = no discoloration, 1 = low, 2 - moderate, 3 - severe.

Table 6. Visual injury, tuber quality and specific gravity were evaluated in the field on 'Monona' potato vines treated with postemergence applications of dinoseb with ammonium sulfate, ethephon, and crop oil.

Dinoseb Rate (kg/ha)	Ammonium sulfate Rate (kg/ha)	Ethephon Rate (kg/ha)	Concentrated oil (L/ha)	Visual Injury Rating (After 10 Days)	Tuber Skinning (25 tubers)	Specific Gravity	Tuber Discoloration (25 tubers)
0.0	0.0	0.0	0.0	3.0[b] d	1.4[c]	1.068	0.0[d]
1.4	0.0	0.0	0.0	7.1 b	0.4	1.065	0.0
1.4	0.0	0.0	2.3	7.2 b	0.2	1.064	0.0
1.4	9.0	0.0	2.3	9.0 a	0.1	1.066	0.0
0.0	9.0	0.0	0.0	3.1 d	0.4	1.069	0.0
1.4	0.0	9.0	2.3	9.6 a	1.8	1.064	0.0
0.0	0.0	9.0	0.0	5.6 c	2.4	1.063	0.0

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within column with similar letters are not significantly different at the 1% level by Duncan's multiple rante test.

[c] Ratings were on a 0 to 3 scale; 0 = no skinning, 1 = low, 2 = moderate, 3 = severe.

[d] Ratings were on a 0 to 3 scale; 0 = no discoloration, 1 = low, 2 = moderate, 3 = severe.

Chapter 4

Summary and Conclusion

Greenhouse and field experiments were conducted to evaluate ametryn, dinoseb, endothall, and paraquat as potential chemical harvest aids for navy bean. Dinoseb alone caused little or no desiccation. Ametryn, endothall, and paraquat individually showed moderate desiccation.

The inclusion of additives to herbicide sprays increased their efficacy. The three-way combination of ammonium sulfate at 4.5 or 9.0 kg/ha and crop oil at 2.3 L/ha with ametryn markedly increased desiccation of navy bean plants and was the most effective ametryn treatment. All of the additives except ammonium thiocyanate provided increased endothall efficacy on navy bean plants. The three-way combinations of dinoseb or ethephon plus ammonium salts plus crop oil were generally more effective than the two-way combinations. Ammonium sulfate applied at 4.5 and 9.0 kg/ha markedly increased efficacy of paraquat. Paraquat applied at 1.1 kg/ha in combination with ammonium sulfate provided the greatest navy bean desiccation. Field studies indicate paraquat at 0.6 kg/ha in combination with 9.0 kg/ha or ammonium sulfate had no adverse effects on navy bean germination or seed dry weight.

Greenhouse and field experiments were conducted to evaluate ammonium salts and ethephon as additives to increase efficacy of dinoseb and endothall for potato vine killing. In the greenhouse ethephon at 9.0 kg/ha plus crop oil at 2.3 L/ha was the most effective of the ethephon treatments, however, desiccation was still poor. Ethephon or ammonium sulfate at 4.5 and 9.0 kg/ha plus crop oil at 2.3 L/ha markedly increased the efficacy of dinoseb for 'Superior' potato vines. In the field, ethephon at 9.0 kg/ha, plus crop oil at 2.3 L/ha in combination with dinoseb at 1.4 kg/ha enhanced herbicide activity on 'Monona' potato vines. However, this three-way combination resulted in tuber quality damage, ammonium sulfate at 9.0 kg/ha plus 2.3 L/ha of crop oil enhanced efficacy of dinoseb at 1.4 kg/ha for 'Monona' and 'Sebago' potato vines.

These studies indicate the three-way combination of ammonium sulfate plus crop oil plus dinoseb can increase desiccation of potato vines without detrimental effects on tuber quality. The combination of 9.0 kg/ha ammonium sulfate plus crop oil at 2.3 L/ha plus 1.4 kg/ha dinoseb gave equivalent potato vine kill for 'Sebago' to 2.8 kg/ha dinoseb plus 2.3 L/ha crop oil.

The study indicates that the combination of ammonium sulfate plus paraquat can be effectively used as a chemical harvest aid for navy bean. The three-way combination of ammonium sulfate, plus crop oil, plus dinoseb allow use of lower dinoseb rates for potato vine desiccation.

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APPENDIX

Table A-1. Percent moisture content and visual injury of navy bean plants following postemergence application of ametryn with ammonium salts, ethephon and crop oil.

	Ammonium Salts						
Ametryn Rate (kg/ha)	Phosphate Rate (kg/ha)	Sulfate Rate (kg/ha)	Thiocyanate Rate (kg/ha)	Ethephon Rate (kg/ha)	Crop Oil Rate (L/ha)	Visual Injury Rating (After 10 Days)[a]	Moisture Content (%)
0	0	0	0	0	0	0.0 h[b]	88 a
0	4.5	0	0	0	0	0.0 h	88 a
0	9.0	0	0	0	0	0.0 h	87 ab
0	0	4.5	0	0	0	0.0 h	87 ab
0	0	9.0	0	0	0	0.0 h	88 a
0	0	0	4.5	0	0	0.0 h	88 a
0	0	0	9.0	0	0	0.5 h	86 ab
0	0	0	0	4.5	0	0.5 h	86 ab
0	0	0	0	9.0	0	1.0 h	82 bc
0	0	0	0	0	2.3	0.0 h	89 a
0	0	0	0	0	4.6	0.0 h	89 a
1.1	0	0	0	0	0	8.2 cd	65 jklm
2.2	0	0	0	0	0	4.8 g	76 de
1.1	4.5	0	0	0	0	8.0 cde	66 ijklm
1.1	9.0	0	0	0	0	7.2 def	71 efghi
2.2	4.5	0	0	0	0	7.0 ef	71 efghi
2.2	9.0	0	0	0	0	6.8 ef	72 efgh
1.1	0	4.5	0	0	0	8.5 bc	64 jklm
1.1	0	9.0	0	0	0	9.2 abc	62 lmno
2.2	0	4.5	0	0	0	8.0 cde	69 ghij
2.2	0	9.0	0	0	0	8.5 bc	65 jklm
1.1	0	0	4.5	0	0	4.0 a	78 cd
1.1	0	0	9.0	0	0	8.8 abc	63 klmn
2.2	0	0	4.5	0	0	7.2 def	70 fghi
2.2	0	0	9.0	0	0	7.0 ef	71 efghi
1.1	0	0	0	4.5	0	8.0 cde	69 ghij
1.1	0	0	0	9.0	0	6.9 ef	72 efgh
2.2	0	0	0	4.5	0	6.5 f	73 defg
2.2	0	0	0	9.0	0	8.0 cde	67 hijkl
1.1	0	0	0	0	2.3	9.0 abc	62 lmno
1.1	0	0	0	0	4.6	8.8 abc	63 klmn
2.2	0	0	0	0	2.3	8.8 abc	64 jklm
2.2	0	0	0	0	4.6	8.8 abc	63 klmn
1.1	4.5	0	0	0	2.3	5.0 g	75 def
1.1	9.0	0	0	0	2.3	4.0 g	78 cd
2.2	4.5	0	0	0	2.3	9.0 abc	61 mno
2.2	9.0	0	0	0	2.3	9.0 abc	63 klmn
1.1	0	4.5	0	0	2.3	9.5 ab	57 pq
1.1	0	9.0	0	0	2.3	9.5 ab	58 nop
2.2	0	4.5	0	0	2.3	10.0 a	54 q
2.2	0	9.0	0	0	2.3	10.0 a	54 q
1.1	0	0	4.5	0	2.3	4.2 g	78 cd
1.1	0	0	9.0	0	2.3	8.0 cde	69 hij
2.2	0	0	4.5	0	2.3	8.5 bc	68 hijk
2.2	0	0	9.0	0	2.3	9.0 abc	63 klmn
1.1	0	0	0	4.5	2.3	4.0 g	76 de
1.1	0	0	0	9.0	2.3	9.0 abc	61 mno
2.2	0	0	0	4.5	2.3	8.0 cde	68 ghijk
2.2	0	0	0	9.0	2.3	8.5 bc	66 ijklm

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table A-2. Percent moisture content and visual injury of navy bean plants following postemergence application of endothall with ammonium salts, ethephon and crop oil.

	Ammonium Salts						
Endothall Rate (kg/ha)	Phosphate Rate (kg/ha)	Sulfate Rate (kg/ha)	Thiocyanate Rate (kg/ha)	Ethephon Rate (kg/ha)	Crop Oil Rate (L/ha)	Visual Injury Rating (After 7 Days)[a]	Moisture Content (%)
0	0	0	0	0	0	0.0 h[b]	82 a
0	4.5	0	0	0	0	0.0 h	82 a
0	9.0	0	0	0	0	0.0 h	83 a
0	0	4.5	0	0	0	0.0 h	81 ab
0	0	9.0	0	0	0	0.0 h	83 a
0	0	0	4.5	0	0	0.0 h	84 a
0	0	0	9.0	0	0	0.0 h	84 a
0	0	0	0	4.5	0	0.0 h	82 a
0	0	0	0	9.0	0	0.0 h	84 a
0	0	0	0	0	2.3	0.0 h	83 a
0	0	0	0	0	4.6	0.0 h	83 a
0.6	0	0	0	0	0	8.0 cdef	64 fgh
1.0	0	0	0	0	0	8.8 abcde	60 hi
0.6	4.5	0	0	0	0	9.5 ab	58 ij
0.6	9.0	0	0	0	0	6.5 fa	70 cde
1.0	4.5	0	0	0	0	10.0 a	47 no
1.0	9.0	0	0	0	0	9.2 abc	57 j
0.6	0	4.5	0	0	0	8.8 abcde	62 gh
0.6	0	9.0	0	0	0	8.8 abcde	62 gh
1.0	0	4.5	0	0	0	9.0 abcd	58 ij
1.0	0	9.0	0	0	0	10.0 a	46 no
0.6	0	0	4.5	0	0	6.0 g	74 bc
0.6	0	0	9.0	0	0	7.5 ef	68 cdef
1.0	0	0	4.5	0	0	8.0 cdef	65 efgh
1.0	0	0	9.0	0	0	7.2 fg	67 cdefg
0.6	0	0	0	4.5	0	7.5 ef	67 cdefg
0.6	0	0	0	9.0	0	9.0 abcd	59 hi
1.0	0	0	0	4.5	0	10.0 a	50 lm
1.0	0	0	0	9.0	0	10.0 a	49 mn
0.6	0	0	0	0	2.3	6.5 fg	73 cd
0.6	0	0	0	0	4.6	6.0 g	74 bc
1.0	0	0	0	0	2.3	8.8 abcde	61 hi
1.0	0	0	0	0	4.6	9.0 abcd	60 hi
0.6	4.5	0	0	0	2.3	8.2 bcdef	64 fgh
0.6	8.0	0	0	0	2.3	8.0 cdef	66 defg
1.0	4.5	0	0	0	2.3	9.0 abcd	63 fgh
1.0	9.0	0	0	0	2.3	10.0 a	44 o
0.6	0	4.5	0	0	2.3	9.5 ab	59 hi
0.6	0	9.0	0	0	2.3	10.0 a	56 jk
1.0	0	4.5	0	0	2.3	10.0 a	57 j
1.0	0	9.0	0	0	2.3	10.0 a	45 o
0.6	0	0	4.5	0	2.3	6.0 g	74 bc
0.6	0	0	9.0	0	2.3	7.8 def	68 cdef
1.0	0	0	4.5	0	2.3	9.5 ab	60 hi
1.0	0	0	9.0	0	2.3	10.0 a	53 kl
0.6	0	0	0	4.5	2.3	7.0 fg	70 cde
0.6	0	0	0	9.0	2.3	9.0 abcd	62 gh
1.0	0	0	0	4.5	2.3	10.0 a	48 no
1.0	0	0	0	9.0	2.3	8.8 abcde	63 fgh

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table A-3. Percent moisture content and visual injury of navy bean plants following post emergence application of dinoseb with ammonium salts, ethephon, and crop oil.

Dinoseb Rate (kg/ha)	Ammonium Salts: Phosphate Rate (kg/ha)	Sulfate Rate (kg/ha)	Thiocyanate Rate (kg/ha)	Ethephon Rate (kg/ha)	Crop Oil Rate (L/ha)	Visual Injury Rating (After 7 Days)[a]	Moisture Content (%)
0	0	0	0	0	0	0.0n[b]	83ab
0	4.5	0	0	0	0	0.0n	83ab
0	9.0	0	0	0	0	0.0n	84a
0	0	4.5	0	0	0	0.on	84a
0	0	9.0	0	0	0	0.0n	85a
0	0	0	4.5	0	0	0.0n	84a
0	0	0	9.0	0	0	0.0n	85a
0	0	0	0	4.5	0	2.0lm	80cd
0	0	0	0	9.0	0	2.5kl	79d
0	0	0	0	0	2.3	0.0n	84a
0	0	0	0	0	4.6	0.0n	84a
0.8	0	0	0	0	0	0.5mn	82bc
1.7	0	0	0	0	0	0.0n	84a
0.8	4.5	0	0	0	0	3.5jkl	79d
0.8	9.0	0	0	0	0	7.5cdefg	68gn
1.7	4.5	0	0	0	0	7.5cdefg	68gh
1.7	9.0	0	0	0	0	7.2defg	69gn
0.8	0	4.5	0	0	0	6.8fgh	72f
0.8	0	9.0	0	0	0	3.2kl	80cd
1.7	0	4.5	0	0	0	8.0bcdefg	66hi
1.7	0	9.0	0	0	0	8.5abcdef	63ij
0.8	0	0	4.5	0	0	5.0ij	76e
0.8	0	0	9.0	0	0	9.0abcd	60jkl
1.7	0	0	4.5	0	0	7.8bcdefg	68gh
1.7	0	0	9.0	0	0	8.8abcde	62ijk
0.8	0	0	0	4.5	0	7.0efg	70g
0.8	0	0	0	9.0	0	7.2defg	70g
1.7	0	0	0	4.5	0	9.0abcd	60jkl
1.7	0	0	0	9.0	0	10.0a	51n
0.8	0	0	0	0	2.3	4.2jk	77d
0.8	0	0	0	0	4.6	4.0jk	78d
1.7	0	0	0	0	2.3	6.8fgh	72f
1.7	0	0	0	0	4.6	6.5ghi	73f
0.8	4.5	0	0	0	2.3	5.2hij	76e
0.8	9.0	0	0	0	2.3	6.8fgh	72f
1.7	4.5	0	0	0	2.3	8.5abcdef	64i
1.7	9.0	0	0	0	2.3	8.2abcdefg	67gh
0.8	0	4.5	0	0	2.3	8.0bcdefg	67gh
0.8	0	9.0	0	0	2.3	8.5abcdef	64i
1.7	0	4.5	0	0	2.3	10.0a	54m
1.7	0	9.0	0	0	2.3	9.5ab	60jkl
0.8	0	0	4.5	0	2.3	8.8abcde	64i
0.8	0	0	9.0	0	2.3	9.0abcd	63ij
1.7	0	0	4.5	0	2.3	9.2abc	60jkl
1.7	0	0	9.0	0	2.3	10.0a	52mn
0.8	0	0	0	4.5	2.3	9.0abcd	62ijk
0.8	0	0	0	9.0	2.3	10.0a	48o
1.7	0	0	0	4.5	2.3	10.0a	54m
1.7	0	0	0	9.0	2.3	10.0a	54m

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table A-4. Percent moisture and visual injury content of navy bean plants following postemergence application of paraquat with ammonium salts, ethephon and X-77.

	Ammonium Salts						
Paraquat Rate (kg/ha)	Phosphate Rate (kg/ha)	Sulfate Rate (kg/ha)	Thiocyanate Rate (kg/ha)	Ethepnon Rate (kg/ha)	X-77 Rate (L/ha)	Visual Injury Rating (After 7 Days)[a]	Moisture Content (%)
0	0	0	0	0	0	0.0 k[b]	88 ab
0	4.5	0	0	0	0	0.0 k	88 ab
0	9.0	0	0	0	0	0.0 k	87 ab
0	0	4.5	0	0	0	0.0 k	87 ab
0	0	9.0	0	0	0	0.0 k	87 ab
0	0	0	4.5	0	0	0.0 k	89 a
0	0	0	9.0	0	0	0.0 k	86 abc
0	0	0	0	4.5	0	0.0 k	86 abc
0	0	0	0	9.0	0	0.5 jk	82 abcde
0	0	0	0	0	1.2	0.0 k	89 a
0	0	0	0	0	2.4	0.0 k	89 g
0.6	0	0	0	0	0	7.4 cdef	68 jk
1.1	0	0	0	0	0	8.2 bc	60 no
0.6	4.5	0	0	0	0	0.5 jk	84 abcd
0.6	9.0	0	0	0	0	1.5 ij	80 cde
1.1	4.5	0	0	0	0	7.0 cdef	70 jk
1.1	9.0	0	0	0	0	6.5 def	73 ij
0.6	0	4.5	0	0	0	9.0 ab	58 no
0.6	0	9.0	0	0	0	10.0 a	44 q
1.1	0	4.5	0	0	0	9.5 a	53 op
1.1	0	9.0	0	0	0	10.0 a	33 r
0.6	0	0	4.5	0	0	6.8 cdef	72 ij
0.6	0	0	9.0	0	0	7.0 cdef	72 ij
1.1	0	0	4.5	0	0	6.2 efg	74 hi
1.1	0	0	9.0	0	0	1.0 jk	82 abcde
0.6	0	0	0	4.5	0	6.8 cdef	72 ij
0.6	0	0	0	9.0	0	7.2 cdef	72 ij
1.1	0	0	0	4.5	0	7.0 cdef	71 ij
1.1	0	0	0	9.0	0	4.5 h	77 efg
0.6	0	0	0	0	1.2	7.0 cdef	70 jk
0.6	0	0	0	0	2.4	7.5 cde	69 jk
1.1	0	0	0	0	1.2	9.0 ab	50 pq
1.1	0	0	0	0	2.4	9.0 ab	51 pq
0.6	4.5	0	0	0	1.2	0.5 jk	82 abcde
0.6	9.0	0	0	0	1.2	0.0 k	87 ab
1.1	4.5	0	0	0	1.2	7.5 cde	67 kl
1.1	9.0	0	0	0	1.2	4.0 h	76 fgh
0.6	0	4.5	0	0	1.2	6.0 fg	74 hi
0.6	0	9.0	0	0	1.2	1.0 jk	82 abcde
1.1	0	4.5	0	0	1.2	7.8 bcd	67 kl
1.1	0	9.0	0	0	1.2	8.0 bc	62 mn
0.6	0	0	4.5	0	1.2	6.5 def	72 ij
0.6	0	0	9.0	0	1.2	1.0 jk	82 abcde
1.1	0	0	4.5	0	1.2	6.0 fg	74 hi
1.1	0	0	9.0	0	1.2	2.5 i	80 cde
0.6	0	0	0	4.5	1.2	1.2 jk	82 abcde
0.6	0	0	0	9.0	1.2	1.0 jk	82 abcde
1.1	0	0	0	4.5	1.2	5.0 gh	75 gh
1.1	0	0	0	9.0	1.2	4.5 h	78 ef

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table A-5. Percent shoot moisture and visual injury of 'Superior' potatoes following postemergence application of endothall with ammonium salts, ethephon and crop oil.

Endothall Rate (kg/ha)	Ammonium Salts Phosphate Rate (kg/ha)	Sulfate Rate (kg/ha)	Thiocyanate Rate (kg/ha)	Ethephon Rate (kg/ha)	Crop Oil Rate (L/ha)	Visual Injury Rating (After 10 Days)[a]	Shoot Moisture (%)
0	0	0	0	0	0	0.0 f[b]	91 abc
0	4.5	0	0	0	0	0.0 f	91 abc
0	9.0	0	0	0	0	0.0 f	91 abc
0	0	4.5	0	0	0	0.0 f	90 abc
0	0	9.0	0	0	0	0.0 f	91 abc
0	0	0	4.5	0	0	0.0 f	93 ab
0	0	0	9.0	0	0	0.0 f	94 a
0	0	0	0	4.5	0	0.0 f	92 ab
0	0	0	0	9.0	0	0.0 f	92 ab
0	0	0	0	0	2.3	0.0 f	91 abc
0	0	0	0	0	4.6	0.0 f	91 abc
0.6	0	0	0	0	0	0.0 f	91 abc
0.6	4.5	0	0	0	0	0.0 f	90 abc
0.6	9.0	0	0	0	0	4.0 c	86 cde
0.6	0	4.5	0	0	0	2.0 e	89 abcd
0.6	0	9.0	0	0	0	6.0 b	84 ef
0.6	0	0	4.5	0	0	0.0 f	92 ab
0.6	0	0	9.0	0	0	5.5 b	85 de
0.6	0	0	0	4.5	0	5.8 b	85 de
0.6	0	0	0	9.0	0	2.0 e	89 abcd
0.6	0	0	0	0	2.3	0.5 f	90 abc
0.6	0	0	0	0	4.6	0.5 f	90 abc
0.6	4.5	0	0	0	2.3	0.0 f	91 abc
0.6	9.0	0	0	0	2.3	4.0 c	86 cde
0.6	0	4.5	0	0	2.3	0.0 f	90 abc
0.6	0	9.0	0	0	2.3	0.0 f	90 abc
0.6	0	0	4.5	0	2.3	0.0 f	92 ab
0.6	0	0	9.0	0	2.3	3.0 d	87 bcde
0.6	0	0	0	4.5	2.3	7.5 a	80 f
0.6	0	0	0	9.0	2.3	4.2 c	86 cde

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns with similar letters are not significantly different at the 1% level by Duncan's multiple range test.

Table A-6. Percent shoot moisture and visual injury of 'Superior' potatoes, following postemergence application of dinoseb with ammonium salts, ethephon, and crop oil.

	Ammonium Salts						
Dinoseb Rate (kg/ha)	Phosphate Rate (kg/ha)	Sulfate Rate (kg/ha)	Thiocyanate Rate (kg/ha)	Ethephon Rate (kg/ha)	Crop Oil Rate (L/ha)	Visual Injury Rating (After 10 Days)[a]	Shoot Moisture (%)
0	0	0	0	0	0	0.0 m[b]	90 a
0	4.5	0	0	0	0	0.0 m	89 ab
0	9.0	0	0	0	0	0.0 m	90 g
0	0	4.5	0	0	0	0.0 m	90 a
0	0	9.0	0	0	0	0.0 m	90 a
0	0	0	4.5	0	0	0.0 m	92 a
0	0	0	9.0	0	0	0.0 m	91 a
0	0	0	0	4.5	0	0.0 m	89 ab
0	0	0	0	9.0	0	0.0 m	91 a
0	0	0	0	0	2.3	0.0 m	89 ab
0	0	0	0	0	4.6	0.0 m	89 ab
0.8	0	0	0	0	0	0.0 m	90 a
1.7	0	0	0	0	0	4.0 jk	84 cd
0.8	4.5	0	0	0	0	3.8 k	86 bc
0.8	9.0	0	0	0	0	4.0 jk	86 bc
1.7	4.5	0	0	0	0	7.8 g	69 fg
1.7	9.0	0	0	0	0	8.5 ef	63 ijk
0.8	0	4.5	0	0	0	4.2 jk	84 cd
0.8	0	9.0	0	0	0	6.5 hi	74 e
1.7	0	4.5	0	0	0	7.5 g	70 fg
1.7	0	9.0	0	0	0	8.8 de	62 ijk
0.8	0	0	4.5	0	0	3.8 k	86 bc
0.8	0	0	9.0	0	0	6.2 hi	76 e
1.7	0	0	4.5	0	0	7.8 g	68 fgh
1.7	0	0	9.0	0	0	9.5 abc	55 m
0.8	0	0	0	4.5	0	6.0 i	76 e
0.8	0	0	0	9.0	0	9.2 bcd	57 lm
1.7	0	0	0	4.5	0	8.5 ef	65 hij
1.7	0	0	0	9.0	0	9.5 abc	54 m
0.8	0	0	0	0	2.3	1.0 l	88 ab
0.8	0	0	0	0	4.6	0.0 m	89 ab
1.7	0	0	0	0	2.3	8.0 fg	67 fgh
1.7	0	0	0	0	4.6	8.0 fg	68 fgh
0.8	4.5	0	0	0	2.3	4.5 j	82 d
0.8	9.0	0	0	0	2.3	8.5 ef	66 ghi
1.7	4.5	0	0	0	2.3	9.0 cde	60 kl
1.7	9.0	0	0	0	2.3	9.8 ab	50 n
0.8	0	4.5	0	0	2.3	8.8 de	62 ijk
0.8	0	9.0	0	0	2.3	10.0 a	22 op
1.7	0	4.5	0	0	2.3	10.0 a	26 o
1.7	0	9.0	0	0	2.3	10.0 a	22 op
0.8	0	0	4.5	0	2.3	6.2 hi	74 e
0.8	0	0	9.0	0	2.3	6.8 h	72 ef
1.7	0	0	4.5	0	2.3	6.5 hi	74 e
1.7	0	0	9.0	0	2.3	6.5 hi	74 e
0.8	0	0	0	4.5	2.3	9.0 cde	60 kl
0.8	0	0	0	9.0	2.3	10.0 a	22 op
1.7	0	0	0	4.5	2.3	10.0 a	22 op
1.7	0	0	0	9.0	2.3	10.0 a	21 p

[a] Ratings were on a 0 to 10 scale; 0 = no injury, 10 = death.

[b] Means within columns with similar letters are not significantly different at the 1% level by Duncan's multiple range test.