Spray-Tank-Mix Compatibility of Manganese, Boron, and Fungicide: Solution pH and Precipitation[1]

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ABSTRACT

Foliar application of manganese and boron mixed with pesticides in water solution is a common practice for peanut (*Arachis hypogaea* L.) production. This study was conducted to determine the compatibility of mixing manganese, boron, and leafspot fungicides using water from three sources. Spray mixtures of the chelated manganese salt of ethylene diamine tetra-acetate and the inorganic salts of manganese as manganese sulfate(TECMANGAM™), manganese sulfate monohydrate, manganese chloride, and manganese nitrate were developed using deep-well water, shallow well water, or distilled water. Boron was added to these mixtures using boric acid or disodium octaborate tetrahydrate. In addition, all combinations were mixed with the leafspot fungicides chlorothalonil or cupric hydroxide plus sulfur. Mixtures were equivalent to recommended rates of manganese, boron, and fungicide applied to the foliage in 140 L ha^{-1} of spray volume. Measurements were made of solution pH and manganese remaining in solution after filtration. Development of precipitates was noted. In the deep-well water solution (pH = 8.0), addition of manganese sulfate, manganese sulfate monohydrate and manganese chloride caused precipitates to form. Manganese nitrate and chelated manganese solutions did not form precipitates. Addition of disodium octaborate tetrahydrate increased the tank-mix pH for all waters source, and caused increased precipitation of the manganese inorganic salts, but not the chelated manganese. Use of boric acid in the water lowered solution pH, and all manganese sources remained in solution. Spray-tank-mix pH was critical in keeping all manganese inorganic salts in solution. For all pH levels studied (pH 4.6 to 8.4) the chelated manganese remained in solution without formation of a precipitate. Chemical analyses of the filtrate showed that only 75 to 80% of the inorganic salts of manganese remained in solution with disodium octaborate tetrahydrate, while 100% of the chelated manganese salt remained in solution. Inorganic salts of manganese and disodium octaborate tetrahydrate should not be mixed with chlorothalonil, and none of the manganese materials should be mixed with cupric hydroxide plus sulfur as a spray-tank-mixture for foliar application.

Key Words: Ethylene diamine tetra-acetate, EDTA, chlorothalonil, cupric hydroxide, chelate, manganese sulfate, manganese chloride, manganese nitrate, boric acid, disodium octaborate tetrahydrate, TECMANGAM™, precipitates.

Manganese application to the peanut (*Arachis hypogaea* L.) crop is an important crop production practice in the Virginia-Carolina peanut production area. Foliar application of manganese has been reported to be more effective than soil applied manganese fertilizer at or before planting (Hallock, 1979).

Pesticide usage on peanut is extensive. Several applications of herbicides (Buchanan *et al.*, 1982), insecticides (Smith and Barfield, 1982), and fungicides (Porter *et al.*, 1982) are broadcast over the crop during the growing season. In the Virginia peanut production area, 2 to 4 applications of boron are also broadcast over the crop during the growing season (Swann, 1992). To decrease the number of trips across the field, and thus minimize wheel-traffic injury to the plants and also lower production cost, as many materials as possible are mixed together and sprayed on the crop simultaneously. Since leafspot fungicides are applied several times during the growing season, it is common to mix manganese and boron with the fungicide in the spray water (Phipps *et al.*, 1992).

The two leafspot fungicides most frequently used are chlorothalonil and cupric hydroxide plus sulfur. Chlorothanlonil (tetrachloroisophthalonitrile) is the fungicide used most frequently by peanut growers (averaging 2.6 applications per year to almost all of the Virginia peanut acreage) for the control of early Cercospora leafspot (*Cercospora arachidicola* Hori.) in peanut (Phipps *et al.*, 1992). This fungicide provides excellent leafspot control when applied to the peanut crop on a 14-day spray schedule or according to the peanut leafspot advisory (Phipps, 1992). However, chlorothalonil, applied at rates recommended for control of Cercospora leafspot significantly increases the severity of Sclerotinia blight caused by *Sclerotinia minor* Jagger (Porter, 1980). Where Sclerotinia blight is a problem another fungicide is used for leafspot control or alternated with chlorothalonil in a leafspot control program for commercial peanut production. Cupric hydroxide ($Cu(OH)_2$) plus sulfur is the fungicide most frequently used, averaging 1.7 applications per year to 66% of the Virginia peanut acreage (Phipps *et al.*, 1992).

The manganese source most commonly used as a foliar spray for commercial peanut production is manganese sulfate (TECMANGAM™) (Swann, 1992). Several other products currently being evaluated are equally effective in supplying manganese to the plant through foliar application. These include manganese chloride ($MnCl_2$), the chelated manganese salt of ethylene diamine tetra-acetate (EDTA), manganese nitrate tetrahydrate ($Mn(NO_3)_2 \bullet 4H_20$) and manganese sulfate monohydrate ($MnSO_4 \bullet H_20$).

The recommended source of boron is sodium borate (disodium octaborate tetrahydrate, $Na_2B_80_{13} \bullet 4H_20$) because it is very soluble in water and can be applied as a foliar spray to peanuts. Boric acid (H_3BO_3) is proving to be a good source of boron for foliar application to peanuts. It is less soluble in water than sodium borate but soluble enough to provide the amount needed for foliar application to peanuts.

Quality of water used for pesticide and fertilizer applications varies. Adamsen (1989) reported deep well (142 m) water in Suffolk, Virginia to have an average Na concentration of 220 mg L^{-1}, a sodium adsorption ratio (SAR) of 103, and a pH of 8.5 while shallow well (10 m) water had an average Na concentration of 4.8 mg L^{-1}, a SAR of 3.1 and a pH of 4.8. The pH of surface water varies considerably.

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The pH of spray water has an effect on insecticide performance (Gorsuch and Griffin, 1992; Hock, 1985). Two well known insecticides used for peanut production (acephate and carbaryl) are greatly affected by water pH. At a solution pH of 3.0 acephate has a halflife of 66 days while in a solution pH of 9.0 the halflife is reduced to 3 days. At a solution pH of 6.0 carbaryl has a halflife of 100-150 days while the same material added into a solution with a pH of 9.0 has a halflife of 24 hours.

The objective of this study was to determine the solution pH and the compatibility of mixing manganese fertilizer materials with boron, leafspot fungicides, and three sources of spray water.

Materials and Methods

A laboratory study was conducted using distilled, deep well (150 m), and shallow well (10 m), waters as the water source for a spray-tank mixture. A spray volume equivalent to 140 L ha^{-1} was used. All mixtures were made to a 50 ml final volume, manually agitated and allowed to sit for at least two hours before centrifugation and filtration. Each mixture was made in triplicate; two samples were used for chemical analyses and one for pH determination. Measurements of pH were made using a Beckman pH meter utilizing a calomel combination electrode with KCl. The pH readings were automatically corrected for temperature during pH measurements by utilizing thermistor compatible thermocompensation. All samples were evaluated visually for the formation of precipitates. The two samples used for chemical analysis were centrifuged and then filtered using gravity filtration through Whatman 42 filter paper (particle retention of 2.5 µm). After filtration the samples were diluted to 100 mL with 0.5 N HCl. Additional dilutions were made with 0.5 N HCl as needed for chemical analysis. Analyses for manganese and copper were made using a Perkin-Elmer 2380 atomic absorption spectrophotometer with an air/acetylene flame with a slit width of 0.7 mm. A combination hollow cathode tube calibrated for Cu, Fe, Mn, and Zn detection was used. Manganese was analyzed at a wavelength of 279.5 nm and copper at a wavelength of 324.8 nm.

Materials used to form the various tank mixes are listed in Table 1. Sources of manganese and boron were commercial grade fertilizer materials. The leafspot fungicides, chlorothalonil and cupric hydroxide plus sulfur, were supplied by the manufacturer. Except for the manganese EDTA all manganese sources were inorganic salts. The spray-tank mixture consisted of 1.12 kg ha^{-1} of Mn as the inorganic salt, 0.19 kg ha^{-1} of chelated manganese (MnEDTA), 0.56 kg ha^{-1} of B (1X amount) and/or 1.12 kg ha^{-1} of B (2X amount). Fungicides were mixed at the rate of 1.75 L ha^{-1} of chlorothalonil (0.94 L a.i.) and 4.67 L ha^{-1} of cupric hydroxide plus sulfur (1.98 L a.i.).

Table 1. Commercial fertilizer materials and fungicides used to prepare tank-mix formulations.

Commercial Product	Element	Percent Element (wt)	Physical State
Manganese Chloride ($MnCl_2$)	Mn	43	flakes
Manganese EDTA[†]	Mn	13	granular
Manganese Nitrate Tetrahydrate ($Mn(NO_3)_2 \cdot 4H_2O$)	Mn	15	liquid
Manganese Sulfate ($MnSO_4$)[‡]	Mn	28.5	powder
Manganese Sulfate Monohydrate ($MnSO_4 \cdot H_2O$)	Mn	32	powder
Boric Acid (H_3BO_3)	B	17.5	crystaline
Sodium borate ($Na_2B_8O_{13} \cdot 4H_2O$)[§]	B	20.5	powder
Chlorothalonil (Bravo 720™)	a.i.[¶]	54	liquid
Cupric Hydroxide (Kocide 404S™)	a.i.[#]	42.5	liquid

[†] EDTA = ethylene diamine tetra-acetate.

[‡] TECMANGAM™

[§] Disodium octaborate tetrahydrate (SOLUBOR™).

[¶] a.i. = active ingredient (Tetrachloroisophthalonitrite).

[#] contains 27% cupric hydroxide and 15.5% sulfur.

Results

Solution pH for the spray-tank-mixtures is reported in Table 2. Ranking of the source water pH was shallow well water < deep well water. With the addition of sodium borate the solution pH increased above that for water alone and was the same for the three water sources. When boric acid was used as the boron source solution pH was decreased below that of water alone and the ranking became distilled water $\simeq$ shallow well water < deep well water. Solution pH for any of the mixtures in water without pesticide, and the corresponding mixture in water with chlorothalonil did not differ. This was also true for the corresponding mixtures of the manganese sources, sodium borate and cupric hydroxide plus sulfur. However, the remaining mixtures of manganese and boron added to water with cupric hydroxide plus sulfur increased solution pH to 1 to 2 units greater than the corresponding mixtures with only water, or water with chlorothalonil. Of the manganese sources, $Mn(NO_3)_2 \bullet 4H_2O$ lowered the solution pH the most. This result was expected since $Mn(NO_3)_2 \bullet 4H_2O$ has a solution pH of 1.0 at 15°C according to its label.

Visual observations of the spray-tank-mixtures (Table 3) show that mixtures of sodium borate or boric acid with each of the three water sources produced a clear solution. For water without pesticide the addition of $MnSO_4 \bullet H_2O$ and $MnCl_2$ caused a slight precipitate to form in the distilled water, shallow well water and deep well water. Addition of $MnSO_4$ to the three water sources produced a slight precipitate in the deep well water. MnEDTA and $Mn(NO_3)_2 \bullet 4H_2O$ produced clear solutions. Addition of the four inorganic salts of manganese to water with sodium borate produced a heavy precipitate in all three water sources. The MnEDTA mixed with water and sodium borate remained a clear solution. With the use of boric acid as the boron source instead of sodium borate, the solutions were clear, or contained a slight precipitate. The slight precipitate may have been the result of undissolved boric acid in the mixture.

For the manganese mixtures with chlorothalonil the appearance of the solution was essentially the same as that with water without pesticide. Because of the milk-white color of the solution, the visual observations are reported as a "normal" solution instead of a clear solution. A heavy precipitate appeared in the solutions formed with sodium borate, any of the four inorganic salts of manganese, and water with chlorothalonil. Otherwise, all other mixtures appeared to be normal solutions. The MnEDTA had no abnormal visual effect on the mixture.

Mixing any of the boron materials with cupric hydroxide plus sulfur produced what appeared to be a normal solution when compared to a mixture of cupric hydroxide plus sulfur and water. With the addition of any of the inorganic salts of manganese to the cupric hydroxide plus sulfur solutions, flocculation occurred. All of the cupric hydroxide plus sulfur settled out of solution leaving a clear supernatant. Addition of the MnEDTA to the cupric hydroxide plus sulfur solution initially produced what appeared to be a normal solution. However, when the solution was allowed to stand undisturbed for 24 hours a precipitate did appear at the bottom, and the water solution at the top had a deep blue color indicating a chemical reaction or exchange.

The manganese remaining in solution after filtration of the spray-tank mixture is reported in Table 4. In water without pesticide mixtures there was less manganese remaining in solution when the inorganic salts of manganese were added to water with sodium borate, than in the mixtures with the inorganic salts and water alone. Use of boric acid instead of sodium borate as the boron source resulted in more manganese remaining in solution. With double the amount of boric acid added, the amount of the manganese remaining in solution increased, especially in the deep well water. The MnEDTA was unaffected by boron in both the shallow well and deep well waters. However, with distilled water there was a decrease of manganese remaining in solution with the addition of boron to the mixture. When manganese was added to a water-with-chlorothalonil mixture, the results were similar to the water only mixture with or without the addition of boron.

The addition of manganese to water with cupric hydroxide

Table 2. Solution pH for the spray-tank mixture.

	WATER[†]			$MnSO_4$			$MnSO_4 \cdot H_2O$			$MnCl_2$			$Mn(NO_3)_2 \cdot 4H_2O$			MnEDTA		
	DW	SWW	DWW	DW	SWW	DWW	DW	SWW	DWW	DW	SWW	DWW	DW	SWW	DWW	DW	SWW	DWW
	---pH---																	
WATER WITHOUT PESTICIDE																		
Water	6.8	4.7	8.0	4.9	4.9	6.4	4.7	4.6	6.5	5.3	6.1	6.0	2.9	3.0	6.2	6.5	6.0	8.2
+ Sodium Borate	8.4	8.4	8.4	7.6	7.6	7.6	7.6	7.6	7.6	7.0	7.1	7.1	7.0	7.1	7.0	8.4	8.4	8.4
+ Boric Acid (1X)[‡]	4.2	4.1	6.1	4.3	4.3	5.8	4.4	4.5	5.8	4.8	4.7	5.5	2.9	3.0	5.4	5.3	5.1	6.4
+ Boric Acid (2X)	-	3.7	5.0	-	3.6	4.8	-	3.7	4.8	-	3.6	4.4	-	2.6	4.4	-	4.6	5.1
WATER WITH CHLOROTHALONIL																		
Water	-	5.1	8.0	-	4.6	6.2	-	4.6	6.5	-	5.7	6.0	-	3.1	6.2	-	6.2	8.4
+ Sodium Borate	-	8.4	8.4	-	7.5	7.5	-	7.5	7.6	-	7.1	7.1	-	7.1	7.0	-	8.4	8.4
+ Boric Acid (1X)	-	4.5	6.6	-	4.4	6.1	-	4.5	5.8	-	4.9	5.7	-	3.1	5.5	-	5.3	6.6
+ Boric Acid (2X)	-	4.0	5.4	-	3.6	5.2	-	3.7	5.2	-	3.7	4.8	-	2.7	4.7	-	4.7	5.6
WATER WITH CUPRIC HYDROXIDE PLUS SULFUR																		
Water	-	8.9	9.0	-	6.6	7.4	-	6.8	7.4	-	6.4	6.5	-	6.3	6.4	-	9.6	9.5
+ Sodium Borate	-	8.4	8.4	-	7.6	7.6	-	7.6	7.5	-	7.1	7.0	-	7.0	7.0	-	8.5	8.5
+ Boric Acid (1X)	-	6.9	6.7	-	6.1	6.4	-	6.1	6.1	-	5.7	5.7	-	5.5	5.6	-	7.3	7.3
+ Boric Acid (2X)	-	6.1	6.3	-	5.5	5.6	-	5.5	5.6	-	5.0	5.2	-	4.9	5.1	-	6.4	6.5

[†] DW = distilled water; SWW = shallow well water; DWW = deep well water; [‡] 1X = 0.56 kg B ha^{-1}; 2X = 1.12 kg B ha^{-1}.

Table 3. Visual observations of the spray-tank mixture.

	WATER[†]			$MnSO_4$			$MnSO_4 \cdot H_2O$			$MnCl_2$			$Mn(NO_3)_2 \cdot 4H_2O$			MnEDTA		
	DW	SWW	DWW	DW	SWW	DWW	DW	SWW	DWW	DW	SWW	DWW	DW	SWW	DWW	DW	SWW	DWW
	---observation[‡]---																	
WATER WITHOUT PESTICIDE																		
Water	C	C	C	C	C	SP	SP	SP	SP	SP	SP	SP	C	C	C	C	C	C
+ Sodium Borate	C	C	C	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP	HP	C	C	C
+ Boric Acid (1X)[§]	C	C	C	C	C	SP	SP	SP	SP	C	C	SP	C	C	SP	C	C	C
+ Boric Acid (2X)	-	C	C	-	SP	SP	-	SP	SP	-	C	SP	-	C	SP	-	C	C
WATER WITH CHLOROTHALONIL																		
Water	-	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS
+ Sodium Borate	-	NS	NS	-	HP	HP	-	HP	HP	-	HP	HP	-	HP	HP	-	NS	NS
+ Boric Acid (1X)	-	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS
+ Boric Acid (2X)	-	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS
WATER WITH CUPRIC HYDROXIDE PLUS SULFUR																		
Water	-	NS	NS	-	F	F	-	F	F	-	F	F	-	F	F	-	NS	NS
+ Sodium Borate	-	NS	NS	-	F	F	-	F	F	-	F	F	-	F	F	-	NS	NS
+ Boric Acid (1X)	-	NS	NS	-	F	F	-	F	F	-	F	F	-	F	F	-	NS	NS
+ Boric Acid (2X)	-	NS	NS	-	F	F	-	F	F	-	F	F	-	F	F	-	NS	NS

[†] DW = distilled water; SWW = shallow well water; DWW = deep well water; [‡] C = clear soultion; F = flocculated; HP = heavy precipitate; NS = normal solution; SP = slight precipitate; [§] 1X = 0.56 kg B ha^{-1}; 2X = 1.12 kg B ha^{-1}.

plus sulfur caused serious problems. There was less manganese remaining in solution in the water with cupric hydroxide plus sulfur mixes than with water without pesticide, or water with chlorothalonil. The MnEDTA was most affected by the cupric hydroxide and sulfur. In the deep well water as much as 32% of the MnEDTA was removed from solution with cupric hydroxide plus sulfur, whereas, only 0 to 9% of the MnEDTA was removed from solution in water without pesticide or water with chlorothalonil. MnEDTA was less affected in the shallow well water with only 19 to 23% removed from solution when added to water, water plus sodium borate, or water plus 1X boric acid. Removal increased to 33% with water plus 2X boric acid. The amount removed in water without pesticide or water with chlorothalonil ranged from 2 to 13%.

Copper remaining in solution after filtration is reported in Table 5 for the water with cupric hydroxide plus sulfur mixture. The high values reported for water, and water plus boron, was a result of being unable to remove all the cupric hydroxide plus sulfur from solution with centrifugation and filtration. Much of the material remained in suspension because of the small particle size of the cupric hydroxide plus sulfur. With the addition of any of the four inorganic salts of manganese to the solution, small amounts of copper were found in the clear solution. With the addition of sodium borate to the solution the amount of copper found in solution did not change very much. With $MnSO_4$ and $MnSO_4 \bullet 4H_20$, the copper found in solution ranged from 13.0 to 18.8 mg kg^{-1}. When $MnCl_2$ or $Mn(NO_3)_2 \bullet 4H_2O$ were added, the values were lower ranging from 2.4 to 8.1 mg kg^{-1}. With the use of boric acid as the boron source instead of sodium borate, the amount of copper found in solution doubled for the shallow well water and tripled for the deep well water when using $MnSO_4$ or $MnSO_4 \bullet 4H_2O$ as the manganese source. When the amount of boron in solution was doubled using boric acid, the amount of copper remaining in solution was approximately doubled, except for the $Mn(NO_3)_2 \bullet 4H_2O$ solution, where it was more than tripled in the shallow well

Table 4. Manganese remaining in solution for the various spray-tank mixtures.

	$MnSO_4$			$MnSO_4 \cdot H_2O$			$MnCl_2$			$Mn(NO_3)_2 \cdot 4H_2O$			MnEDTA		
	DW[†]	SWW[‡]	DWW[§]	DW	SWW	DWW	DW	SWW	DWW	DW	SWW	DWW	DW	SWW	DWW
	percent														
WATER WITHOUT PESTICIDE															
Water	94	96	96	86	91	88	85	78	80	93	92	86	97	92	92
+ Sodium Borate	89	86	77	78	68	78	74	73	74	84	82	73	87	92	92
+ Boric Acid (1X)[¶]	87	88	90	91	90	90	81	82	84	90	88	86	88	91	93
+ Boric Acid (2X)	-	93	96	-	90	93	-	79	87	-	85	91	-	92	91
WATER WITH CHLOROTHALONIL															
Water	-	97	89	-	87	84	-	80	83	-	90	87	-	89	98
+ Sodium Borate	-	86	78	-	84	74	-	75	72	-	84	77	-	87	100
+ Boric Acid (1X)	-	92	87	-	86	84	-	80	79	-	87	88	-	87	100
+ Boric Acid (2X)	-	93	97	-	90	92	-	81	86	-	91	96	-	98	98
WATER WITH CUPRIC HYDROXIDE PLUS SULFUR															
Water	-	85	83	-	81	80	-	74	71	-	82	77	-	81	69
+ Sodium Borate	-	71	60	-	73	70	-	68	61	-	72	68	-	81	76
+ Boric Acid (1X)	-	86	83	-	84	80	-	78	74	-	78	79	-	77	68
+ Boric Acid (2X)	-	81	84	-	79	80	-	79	82	-	85	86	-	67	70

[†] DW = distilled water; [‡] SWW = shallow well water; [§] DWW = deep well water; [¶] 1X = 0.56 kg B ha^{-1}; 2X = 1.12 kg B ha^{-1}.

Table 5. Copper in solution for the cupric hydroxide plus sulfur spray-tank mixtures.

	Water[†]		$MnSO_4$		$MnSO_4 \cdot H_2O$		$MnCl_2$		$Mn(NO_3)_2 \cdot 4H_2O$		MnEDTA	
	SWW	DWW	SWW	DWW	SWW	DWW	SWW	DWW	SWW	DWW	SWW	DWW
	mg kg^{-1}											
Water	1458	1610	14.0	17.0	13.6	14.8	2.8	6.7	5.2	8.1	1732	1443
+ Sodium Borate	1320	1147	18.8	13.0	16.8	11.1	4.0	5.2	2.4	6.3	1714	1517
+ Boric Acid (1X)[‡]	1380	1129	37.2	39.6	34.3	35.5	25.2	28.1	32.9	31.1	1696	1554
+ Boric Acid (2X)	1197	1102	58.0	65.0	65.0	57.0	61.0	48.0	110.0	63.0	1518	1444

[†] SWW - shallow well water; DWW = deep well water; [‡] 1X = 0.56 kg B ha^{-1}; 2X = 1.12 kg B ha^{-1}.

water. For the MnEDTA mixture, the amount of copper found in solution was 300 to 400 mg kg^{-1} greater than the water with cupric hydroxide plus sulfur mixture, when boron was added to the solution. Without boron in the mixture, the copper in shallow well water increased 274 mg kg^{-1} and in deep well water decreased 167 mg kg^{-1}.

Discussion

The results of this research were used to develop a spray-tank mixture compatibility chart for the various manganese, boron, and fungicide mixtures studied (Table 6).

The following general guidelines were developed.

1. Mixing any of the manganese materials with water, or with water and boric acid was a compatible mix.

2. Mixing the manganese inorganic salts with water and sodium borate was not a compatible mix. Because of the removal of manganese from solution, and the formation of a precipitate which can hinder effective spray coverage, these mixtures should be avoided.

3. MnEDTA mixed with water and boron, either sodium borate or boric acid, was a compatible mix.

4. Results were the same when chlorothalonil was added to water, boron, and manganese mixtures. Use of sodium borate with the manganese inorganic salts must be avoided.

5. Non of the manganese materials and boron should be mixed with cupric hydroxide plus sulfur. Not only was there considerable loss of manganese from solution, but the manganese inorganic salts caused a flocculation of the mixture and all the cupric hydroxide plus sulfur material separated from the water and settled to the bottom, leaving a clear supernatant. With the addition of boric acid to the mixture, and the accompanying drop in solution pH, there was a doubling or tripling of the amount of copper released into solution. This increase of copper in solution could be toxic to the plant (Jones, 1991; Römheld and Marschner, 1991). Also, there was some indication from chemical analyses, and the deep blue color of the supernatant after the cupric hydroxide had settled, that the MnEDTA was transformed to copper EDTA. This was demonstrated visually by Martens and Powell (1992). Copper EDTA is a stronger and more stable bonded chelate than MnEDTA (Norvell, 1991) and readily available to the plant and could cause copper toxicity.

6. Solution pH is important when adding chemicals such as insecticides and fungicides to the spray-tank-mix. For example, for Sclerotinia blight control the 1992 manufacturers' label for iprodione (a contact fungicide used on peanut) recommends that the spray solution should be buffered to a pH of 5.0 to 7.0. The label specifies that some chemical breakdown could occur in a solution with a high pH. As additional examples, Gorsuch and Griffin (1992) report the half-life of acephate is 29, 30, 17, and 3 days at a pH of 3.0, 5.0, 7.0 and 9.0 respectively at 40° C. Malathion is stable at pH 5.0-7.0 but rapid hydrolysis occurs in acidic or more alkaline solutions. Carbaryl has a half-life of 100-150 days at pH 6.0, 24-30 days at pH 7.0, 2-3 days at pH 8.0, and 24 hours at pH 9.0 (Hock, 1985).

Based on guideline 6, several of the spray-tank mixtures listed in Table 6, though compatible, would not be suitable for the addition of pesticides that require a solution pH range of 5.0 to 7.0 for greatest effectiveness. For the compatible spray-tank mixtures listed in Table 6, those that use sodium borate as the boron source would not be suitable for mixing with materials that are best suited to a solution pH of 5.0 to 7.0. This restriction includes any mixture of sodium borate and MnEDTA in water without pesticide, or in water with chlorothalonil. Because of the high pH of deep well water alone, deep well water with MnEDTA, deep well water with chlorothalonil, and deep well water with chlorothalonil and MnEDTA, caution must be used when adding other pesticides that are pH dependent. Caution

Table 6. Spray-tank mixture compatibility.

	Water[†]			$MnSO_4$			$MnSO_4 \cdot H_2O$			$MnCl_2$			$Mn(NO_3)_2 \cdot 4H_2O$			MnEDTA		
	DW	SWW	DWW	DW[‡]	SWW	DWW	DW	SWW	DWW	DW	SWW	DWW	DW	SWW	DWW	DW	SWW	DWW
	---observation[‡]---																	
								WATER WITHOUT PESTICIDE										
Water	Y	Y	YP	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	YP
+ Sodium Borate	YP	YP	YP	N	N	N	N	N	N	N	N	N	N	N	N	YP	YP	YP
+ Boric Acid (1X)[§]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
+ Boric Acid (2X)	-	Y	Y	-	Y	Y	-	Y	Y	-	Y	Y	-	Y	Y	-	Y	Y
								WATER WITH CHLOROTHALONIL										
Water	-	Y	YP	-	Y	Y	-	Y	Y	-	Y	Y	-	Y	Y	-	Y	YP
+ Sodium Borate	-	YP	YP	-	N	N	-	N	N	-	N	N	-	N	N	-	YP	YP
+ Boric Acid (1X)	-	Y	Y	-	Y	Y	-	Y	Y	-	Y	Y	-	Y	Y	-	Y	Y
+ Boric Acid (2X)	-	Y	Y	-	Y	Y	-	Y	Y	-	Y	Y	-	Y	Y	-	Y	Y
								WATER WITH CUPRIC HYDROXIDE PLUS SULFUR										
Water	-	YP	YP	-	N	N	-	N	N	-	N	N	-	N	N	-	N	N
+ Sodium Borate	-	YP	YP	-	N	N	-	N	N	-	N	N	-	N	N	-	N	N
+ Boric Acid (1X)	-	Y	Y	-	N	N	-	N	N	-	N	N	-	N	N	-	N	N
+ Boric Acid (2X)	-	Y	Y	-	N	N	-	N	N	-	N	N	-	N	N	-	N	N

[†] DW = distilled water; SWW = shallow well water; DWW = deep well water; [‡] Y = can mix; N = do not mix; YP = because pH > 7.0 do not mix pesticides which require a solution pH <7.0; [§] 1X = 0.56 kg B ha^{-1}; 2X = 1.12 kg B ha^{-1}.

must also be used for mixtures of shallow well water or deep well water with cupric hydroxide plus sulfur, and caution must be used for these same mixtures with sodium borate.

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