weight is in kilograms, and the flow rate is 300 ml per minute.

In addition to measuring the gaseous exchange of CO_2 and O_2 during respiration, the system can also measure O_2 and CO_2 exchange during photosynthesis since the temperature controlled rooms containing the samples are equipped with adequate illumination for most plants. However, since its initial use in the fall of 1964 it has been used solely for respiratory analysis. The respiratory activity of a wide range of fruits and vegetables has been determined at various temperatures in relation to nutritional, cultural and environmental conditions during growth, maturation, ripening, and senescence; and as affected by pre- and post-harvest chemical treatments. Examples of the time-course change in O_2 consumption or CO_2 production rate for several tissues are depicted in Fig. 3 and 4.

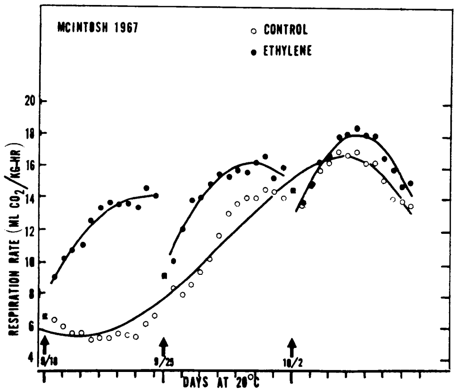

Fig. 4. CO_2 evolution of McIntosh apples at 20°C of fruits at 3 successive harvests and the response to exogenous ethylene. Ethylene treatment was 1000 ppm for 12 hours on the day of harvest.

The system can be employed for simultaneous analysis of O_2 and CO_2, or of either gas independently. The automatic sampling, analyzing, and recording features provide capacity to monitor respiration frequently and over extended time periods. Digital print out and tape punch equipment has been installed to facilitate computerized processing of the data.

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Influence of Fat-Sugar Derived Surfactants on Phosphorus Absorption Through Leaf Surfaces[1]

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Abstract. Fat-sugar derived surfactants were examined as to their effectiveness in the promotion of absorption of nutrient ions through leaf surfaces and subsequent translocation of these ions through the plant. The fat-sugar derived surfactants and several other commercial surfactants were added to solutions of P to test the effectiveness of the surfactants in promoting ion absorption and translocation.

The surfactants in the nutrient sprays at a 0.5% concentration were generally more effective than at 0.1% or 1.0% concentration with the exception of Polyoxyethylenated Tallow Sucroglyceride (PTS) which had its greatest effect at a 1.0% concentration. Sucro sperses and Sucro sols with 3 fatty acid molecules per sucrose molecule were more effective in increasing P uptake and transport than formulations with 1.5 or 4.5 fatty acid molecules per sucrose molecule. A 40:1 ratio of ethylene oxide to sucrose was most effective for increase of P absorption. Combining PTS and Sucroglyceride T-110 (T-110) increased P absorption more than if either surfactants were used alone. Ratios of 1:3 or 3:1 respectively, were most effective. T-110 and Sucrose Monotallowate (SMT) did not significantly increase absorption of P at any concentration tested. PTS was effective in increasing nutrient ion uptake at a 1% concentration, but it was found to be somewhat phytotoxic at this level. The fat-sugar complexes used as surfactants increased ion uptake in some instances more than 20 times compared to using no surfactant. When these same surfactants were compared to commercially used surfactants, they generally proved to be superior for use with the foliar applied nutrients.

Introduction

When soil conditions favor nutrient fixation or insolubility of compounds of the nutrient then foliar application produces the most efficient plant response to these ions, especially those required in low total amounts by the plant. Various spray additives have been used to increase the rate and amount of nutrient ion absorption (see literature citations). Among these, the use of wetting agents such as the Tweens, X-77, Tergitol surfactants, etc., are probably most common. Surfactants reduce surface tension of solutions and allow a greater contact area to be maintained. The surface tension can be reduced enough to overcome adverse effects of air pockets caused by leaf surface hairs and wax and to facilitate penetration into the stomatal aperatures. Sugars have also been added to various spray solutions to regulate uptake more closely and to facilitate translocation of the substance once inside the plant (4, 10).

Fat-sugar derived surfactants were examined as to their effectiveness in the promotion of absorption of P ions through leaf surfaces, and subsequent translocation of these ions through the plant.

Materials and Methods

Snap bean '83 Tendercrop' seedlings were grown in soil, one plant per 4 inch pot in the greenhouse. The soil was mixed with peat moss at a 1:1 ratio and adjusted to pH 6.5 with lime. Nitrogen, P, and K were added at an equivalent of 150, 150 and 300 lb./acre (A), respectively.

The plants were allowed to grow for 21 days after emergence at which time they were treated. The treating solution contained the desired surfactant plus a 500 ppm P solution of radioactive Na H_2 $^{32}PO_4$ with an activity of 0.5 uc/ml as P^{32}. This solution was adjusted to pH 2.5 with 1 *N* HCl.

The following materials were tested as surfactant adjuvants at 0.1%, 0.5%, and 1.0% concentrations: Sucro-sperse 30-13, Sucro-sperse 30-115, Sucro-sperse 30-145, Sucro-sol 20-115, Sucro-sol 40-13, Sucro-sol 40-115, Sucro-sol 60-13, Sucro-sol 60-115, Sucro-sol 60-145, Sucrose Monotollowate (SMT), Polyoxyethylenated Tallow Sucroglyceride (PTS), Sucroglyceride T-110 (T-110), Tween 20 (polyoxyethylene sorbitan monolaurate) a nonionic surfactant, Tween 80 (polyoxyethylene sorbitan monolaurate-ester) a non-

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ionic surfactant, Dupanol (mixture of sodium lauryl sulphate and sodium dodecyl sulphate) an anionic surfactant, X-77 (alkylarylpolyethylene glycols plus free fatty acids and isopropanol) a nonionic surfactant, sucrose, mixtures of PTS and T-110 in the following ratios, respectively: 3.75: 1.25, 2.5:2.5, 1.25:3.75. The fat sugar derived surfactants are all classed as nonionic surfactants.

Samples of PTS were also tested at concentrations of 2, 3, and 5% since early results pointed to increased effectiveness at higher concentrations. A water control without surfactant was run with each group of test plants. Each treatment was replicated 4 times.

The Sucro-sperses and Sucro-sols were furnished by Colonial Sugars of Gramercy, Louisiana, as experimental surfactants. They are ethoxylated sucrose esters that are either water soluble or water dispersible. The Sucro-sol preparations are water soluble while the Sucro-sperse preparations are water dispersible. The first figure (20, 30, 40, 60) of the code numbers refers to the number of ethylene oxide molecules per molecule of sucrose in the preparation. The first digit following the dash indicates the source of the fatty acid used for the production of the surfactant. In the case of the surfactants listed above, this number was always one which indicates that the fatty acids were derived from tallow. The second and third digits following the dash indicate the units and tenths of fatty acid molecules esterified with each molecule of sucrose. For example, the material designated as Sucro-sol 20-115 is a water soluble product containing 20 molecules of ethylene oxide per mole of sucrose, with the fatty acids derived from tallow, and 1.5 fatty acid molecules per sucrose molecule.

SMT, also a product of Colonial Sugars, is another sucrose-tallow combination which is water dispersible.

T-110 and PTS were furnished by Ledoga, S.p.A., Milan, Italy. The T-110 was produced by a direct interaction of sucrose with tallow. The T-110 has approximately one molecular weight of tallow reacted with approximately one half molecular weight of sucrose in which a considerable amount inverts to fructose and glucose. The PTS was treated with a relatively high percentage of ethylene oxide to make it very hydrophilic. The addition of the latter in small quantities to T-110 yields a product with a more desirable affinity for water.

Table 1. Absorption measured as CPM phosphorus-32 translocated in bean plants into base leaflets of first trifoliate leaf influenced by the addition of various surfactants.

Duncan's Multiple Range Test for 0.5% concentration	Surfactant treatment	Per cent concentration of surfactant			Surfactant treatment means
		0.1	0.5	1.0	
			CPM		
	Sucrose	10	21	9	13
	Dupanol	9	24	10	14
	X-77	6	31	9	15
	Sucroglyceride T-110	28	31	40	33
	PTS:T-110 2.5:2.5	24	34	35	31
	Control (no surfactant)	11	34	26	24
	Sucro-sperse 30-145	30	45	82	52
	Sucro-sol 20–115	42	56	34	44
	Sucro-sperse 30–13	11	67	109	62
	Tween 80	13	80	66	53
	PTS:T-110 3.75:1.25	142	81	112	113
	Sucro-sol 60–13	19	90	91	67
	Tween 20	11	94	38	48
	Sucrose Monotallowate	26	100	24	50
	Polyoxyethylenated Tallow Sucroglyceride	32	108	177	106
	PTS:T-110 1.25:3.75	250	129	91	157
	Sucro-sperse 30–115	10	133	31	58
	Sucro-sol 60–115	13	142	15	56
	Sucro-sol 60–145	25	155	17	66
	Sucro-sol 40–13	62	242	107	137
	Sucro-sol 40–115	11	254	31	99
	Total treatment means	37	93	55	62
		a	b	c	grand mean
	lsd (.05) =		63		

The beans were individually treated by dipping the center leaf of the oldest group of trifoliate leaves in the labeled solution. Excess solution was allowed to drip off the leaf. The plants were then allowed to grow 24 hr before harvesting. At this time, the treated leaf was cut off and discarded while the remainder of the plant was cut into 3 sections: A – the remaining 2 leaves of the trifoliate and the petiole, B – the growing tip, and C – the 2 cotyledonary leaves plus the stem. Nine leaf disks, one cm in diameter, were extracted from each sample using a cork borer. The disks were placed directly in a counting planchet where they were dried in an oven at 100°C for 45 minutes. After separation of the dried leaf disks in the planchet, they were counted using an end window G-M counter.

Results and Discussion

Base leaflets of first trifoliate leaf. The 0.5% concentration of surfactant was the most effective of the 3 concentrations tested as presented in Table 1. In most cases a relatively small amount of P^{32} was translocated into the 2 leaves adjoining the treated leaf in the first petiole. However, significant differences were found among surfactants. Generally, at the 0.5% concentration, the sucrose-tallow surfactants significantly increased absorption and transport of P into the base leaflets of the first trifoliate leaf compared to using no surfactant.

For increasing P content of these leaflets the Sucro-sols seemed to be superior to the Sucro-sperses, with the exception of 20-115. The amount of fatty acid per sucrose molecule had less effect but combinations having 1.5

Table 2. Absorption measured as CPM of P^{32} translocated in bean plants into plant apical tissue as influenced by the addition of various surfactants.

Duncan's Multiple Range Test for 0.5% concentration	Surfactant treatment	Per cent concentration of surfactant			Surfactant treatment means
		0.1	0.5	1.0	
			CPM		
	Dupanol	24	33	12	23
	Sucrose	35	56	18	36
	X-77	33	57	19	36
	Control	58	92	56	69
	Sucro-sperse 30–115	108	150	82	113
	Polyoxyethylenated Tallow Sucroglyceride	33	156	995	350
	Tween 20	65	185	187	146
	Sucrose Monotallowate	16	224	91	110
	Sucro-sperse 30–145	86	238	82	137
	Tween 80	68	249	135	157
	Sucroglyceride T-110	212	272	185	223
	PTS:T-110 2.5:2.5	179	299	198	225
	Sucro-sol 60–115	102	346	46	165
	Sucro-sol 60–145	39	358	87	161
	Sucro-sol 40–115	91	441	70	201
	Sucro-sperse 30–13	84	455	156	232
	Sucro-sol 60–13	63	496	168	242
	Sucro-sol 20–115	211	508	288	336
	PTS:T-110 3.75:1.25	978	736	748	820
	Sucro-sol 40–13	88	1065	125	426
	PTS:T-110 1.25–3.75	746	1118	798	887
	Total treatment means	158	359	217	244
		a	b	c	grand mean
	lsd (0.05) =		276		

fatty acid molecules seemed to generally promote greater transport into this area.

PTS and T-110 combinations proved to be superior to just using T-110 alone at the 0.5% concentration. Only the ratio of 1.25:3.75 was slightly better than using PTS alone, while the ratio of 2.5:2.5 was no better than using T-110 alone. PTS used alone was more effective at the 1.0% concentration than was the 3.75:1.25 ratio, but the 1.25:3.75 ratio was better used at the 0.1% concentration.

Most of the sucrose derivatives were better than no surfactant or one of the commercial surfactants tested with the exception of Tween 20 and Tween 80.

Apical tissue. The greatest translocation of P was into the apical tissue of the plant (Table 2). This is to be expected since inorganic P is required in relatively large amounts in areas of high metabolic acivity. The amount of P found in the apical tissue gave a better indication of the effectiveness of the surfactants than the base leaves, because of the increased translocation into this part.

All of the surfactants had a greater effect on uptake when they were used at the 0.5% concentration with the exception of PTS and PTS:T-110 at a 3.75:1.25 ratio. These were more effective at the 1.0% and 0.1% concentration, respectively. PTS at a 1.0% concentration increased P transport, hence uptake, 20 fold over the control. PTS was also tested at concentrations of 2, 3, and 5%. At all of these concentrations uptake was facilitated, but not to the extent of the 1% level.

All of the Sucro-sperses and sols, except Sucro-sperse 30-115, and the PTS:T-110 at 2.5:2.5 ratio were generally better than the control and the other commercial surfactants tested. The Sucro-sperses and Sucro-sols containing 3 molecules of fatty acid per sucrose molecule had a more consistant effect on increasing P uptake than did complexes with 1.5 or 4.5 moles. Having 40 molecules of ethylene oxide per sucrose molecule seemed to be slightly more effective than products having 60 or 30, in that order. Decreasing that ratio to 20 ethylene oxide molecules seemed to increase the effectiveness of the surfactant.

Combining PTS and T-110 greatly increased their effectiveness as surfactants (Table 2). Alone or at equal concentrations at the 0.5% concentration neither was better than the control. But, altering their concentration ratio to approximately 1.3 or 3:1 resulted in a surfactant mixture significantly better than most of the other surfactants tested. PTS could still be considered an effective surfactant, but only at higher concentrations.

Dupanol, Sucrose, and X-77 actually decreased absorption of P compared to the control. Tween 20 and Tween 80 promoted uptake but not significantly greater than the no surfactant control.

Cotyledonary leaves and stem. Little or no P was transported into the older cotyledonary leaves (Table 3). This is as expected since the cells are already developed and the metabolic acivity of these cells is at a lower level and the inorganic P requirement is much less. Significant differences between treatments were almost non-existent and the concentration of surfactant had no effect on transport into these areas.

The use of SMT as a surfactant resulted in less nutrient absorption than most of the other fat sugar surfactants tested. Treatment solutions at 0.5% and 1.0% concentration of SMT had a gluey consistency. When treated, the leaf became completely incased with this material, and the excess solution flowed in a steady stream from the treated leaf instead of dripping off the leaf a drop at a time as the other surfactant solutions did. It was thought that this viscous consistency would affect the practicability of this material in spray applications. In test, 0.5% SMT solution was found to pass through an atomizer nozzle quite easily and it had better wetting action than most of the other surfactants tested. The SMT solutions were found to dry within 5 minutes after treatment, which may have contributed to the low absorption.

X-77 clearly aided in spreading the solution on the leaf surface and also left a larger total amount of P^{32} solution on the treated leaf. However, as shown in the results, little P was translocated. X-77 at the 0.5 and 1% concentration caused a severe curling of the treated leaf. A discoloration of this same leaf occurred after 24 hr. This observed phytotoxic effect of X-77 may explain why it gives good results when used as a surfactant additive with herbicide sprays (7, 11).

Table 3. Absorption measured as CPM phosphorus-32 translocated in bean plants into cotyledonary leaves as influenced by the addition of various surfactants.

Surfactant treatment	Per cent concentration of surfactant			Individual treatment means
	0.1	0.5	1.0	
		CPM		
Control (no surfactant)	8	11	10	10
Sucro-sol 20–115	11	12	12	12
Sucro-sperse 30–13	8	13	12	11
Sucro-sperse 30–115	16	11	10	12
Sucro-sperse 30–145	8	11	8	9
Sucro-sol 40–13	10	24	6	13
Sucro-sol 40–115	12	20	9	13
Sucro-sol 60–13	14	14	7	11
Sucro-sol 60–115	8	14	15	13
Sucro-sol 60–145	10	7	9	8
Polyoxyethylenated Tallow Sucroglyceride	9	7	42	19
Sucroglyceride T-110	9	14	12	12
Sucrose Monotallowate	8	6	9	7
PTS:T-110 3.75–1.25	15	21	11	16
PTS:T-110 2.5:2.5	15	14	13	14
PTS:T-110 1.25:3.75	27	17	18	21
Tween 20	8	13	12	11
Tween 80	8	11	11	10
Sucrose	7	9	9	8
X-77	10	7	7	8
Dupanol	8	8	7	8
Total treatment means	11	13	12	12
	a	a	a	grand mean
lsd (.05) =		8		

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