authors. The greater response to Cu in 1966 as compared to 1965 could not be explained on the basis of native soil Cu since this value was approximately the same both years. It is possible that the lower temperatures experienced in 1966 could have accentuated the Cu deficiency by reducing root-growth, thus limiting the soil volume from which the plant could absorb Cu. Copper-deficiency symptoms on plants not fertlized with Cu were much more pronounced in 1966 than in 1965. In 1965 the superphosphate contained 20 ppm Cu; therefore, when superphosphate was added Cu was also added. This may have been sufficient to mask Cu deficiency in the no-Cu treatment, with a resultant higher yield. A similar situation existed in 1966, but the Cu content of the superphosphate was only 9 ppm; therefore, the Cu added as a contaminant was less than in 1965.

The effect of Cu fertilization on yield response to P fertilization is shown in Figure 3. Both Cu and P were necessary to produce optimum yields on virgin flatwood soils. The reduction in yield at the two higher P rates, even when 4 pounds of Cu per acre were added, suggested the possibility of an antagonistic effect of P at the highest rates. The effect of high P absorption on Zn, Cu and Fe uptake has been reported (1, 2, 3) to occur under certain conditions on several crops.

It was evident that on virgin flatwood soils, similar to those on which the above experiments were conducted, the P requirement of watermelons was approximately 105 pounds P (240 lbs. P_2O_5) per acre and the Cu above 2 pounds per acre. With Cu deficiency, response to phosphate fertilization was likely to be much less than where Cu was added or was adequate. Similarly, on new land, when well-limed, P was likely to be a limiting factor on growth and melon yield. From the present studies, both Cu and P were found to be major limiting factors for melon production on flatwood soils. Therefore, the fertilization of melons on these soils should include Cu in the fertilizer unless adequate Cu is known to be present in the soil or suitable Cu sprays are employed.

LITERATURE CITED

1. Bingham, F. T. 1963. Relation between phosphorus and micronutrients in plants. Soil Sci. Soc. Amer. Proc. 27: 389-391.
2. Bingham, F. T. and M. J. Garber. 1960. Solubility and availability of micronutrients in relation to phosphorus fertilization. Soil Sci. Soc. Amer. Proc. 24: 209-213.
3. Burleson, C. A., A. D. Dacus, and C. J. Gerard. 1961. The effect of phosphorus fertilization on the zinc nutrition of several irrigated crops. Soil Sci. Soc. Amer. Proc. 25: 365-368.
4. Dadykin, V. P. 1951. Soil temperature as one of the factors determining the affectiveness of fertilizer. Pachvovedenie: 557-561. (Cited from Proc. Amer. Soc. Hort. Sci. 75: 601-610).
5. Everett, P. H. 1961. The effects of superphosphate on watermelon yields. Proc. Fla. State Hort. Soc. 74: 158-161.
6. Locascio, S. J., P. H. Everett, and J. G. Fiskell. 1964. Copper as a factor in watermelon fertilization. Proc. Fla. State Hort. Soc. 77: 190-194.
Locascio, S. J. and J. G. Fiskell. 1966. Copper requirements of watermelons. Proc. Amer. Soc. Hort. Sci. 88: 568-575.
8. Locascio, S. J. and G. F. Warren. 1960. Interaction of soil temperature and phosphorus on growth of tomatoes. Proc. Amer. Soc. Hort. Sci. 75: 601-610.
9. Robinson, R. R., V. G. Sprague, and C. F. Gross. 1959. The relation of temperature and phosphate placement to growth of clover. Soil Sci. Soc. Amer. Proc. 23: 225-228.

POSTEMERGENCE HERBICIDES FOR CELERY SEEDBEDS[1]

J. R. ORSENIGO[2]

Slow-growing celery seedlings cannot compete effectively with annual weeds for nutrients, water, space and light. The control of weeds essential in celery seedbeds can be time-consuming and expensive. Off-season and preplanting cultivation and flooding programs mitigate but not eliminate weed infestations. Preseeding soil fumigation treatments may not effectively control annual weeds on the organic soils of the Florida Everglades. Mechanical weed control methods are not applicable to broadcast or drill-seeded celery seedbeds. Manual weed control may be costly and tedious; some broadleaf weed species are difficult to distinguish from celery seedlings during thinning, handweeding and transplant pulling operations. CDAA and CDEC[3] are widely used for post-transplanting application (*3*), but these chemicals are not well tolerated by germinating celery seed and young seedlings. Experience in pri-

[1]Florida Agricultural Experiment Stations Journal Series No. 2511.
[2]Associate Horticulturist, University of Florida, Everglades Experiment Station, Belle Glade.

[3]CDAA is 2-chloro-N, N-diallylacetamide. CDEC and other herbicides pertinent to this report are identified in Table 1.

mary evaluation trials[4] and in preliminary experiments led to a judgment that available preemergence herbicides were ill-adapted to celery seedbeds where seed is often broadcast on the bed surface. Efforts were concentrated on the development of effective, safe postemergence chemical treatments.

Low-aromatic solvents—mineral spirits—have been widely used for postemergence weed control in Umbelliferous crops (*1*) although weed control has been erratic and some weed species are poorly controlled at all growth stages. Mineral spirits may injure the terminal bud of celery seedlings and also impart "off-flavors" to the crop.

Since 1957, the search for a wide-spectrum postemergence herbicide tolerated by celery seedlings included numerous chemicals and some combinations. The exceptional tolerance of celery to "Karsil" was noted early in the research programs. This herbicide was evaluated intensively for more than 2 years in celery seedbeds and in transplanted celery (*2*). "Karsil" was a more effective herbicide than solan and less inurious to celery than dicryl, two related chemicals. Solan was studied more thoroughly after the highly promising "Karsil" was not commercialized. Later, solan also was removed from commercial consideration, and the research program again was based on selection from new, potential seedbed herbicides rather than existing promising chemicals.

4Orsenigo, J. R. 1958 et seq. Univedsity of Florida Everglades Station Mimeo Reports: 59-5, 59-6, 59-12, 60-7, 62-1, 63-1, 64-3 and 65-5.

Materials and Methods

Soil type and location: All trials were conducted on Everglades or Okeelanta peaty muck in commercial seedbeds and production fields of cooperating growers.

Experimental design: Randomized complete block designs of 3 and 4 replications were used in all trials. Seedbed randomization was con-

Table 1.--Chemicals evaluated in postemergence herbicide applications to celery seedbeds.

Atlox 209 FG	a nonionic surfactant, Atlas Chemical Industries.
BV-201	1-(3,4-dichlorophenyl)-3-methyl-2-pyrrolidinone, Rohm & Haas.
BV-207	1-(3-chloro-4-methylphenyl)3-methyl-2-pyrrolidinone, Rohm & Haas.
CDEC	2-chloroallyl diethyldithiocarbamate, Monsanto.
dicryl	3',4'-dichloro-2-methylacrylanilide, Niagara Chemical.
EP-238	sodium salt of 4-(2-methyl-4-chlorophenoxy)butyric acid, Morton Chemical.
FW-925	2,4-dichlorophenyl-4-nitrophenylether, Rohm & Haas.
Karsil	N-(3,4-dichlorophenyl)-2-methylpentanamide, Niagara Chemical.
linuron	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea, duPont.
mineral spirits	a low-aromatic hydrocarbon solvent
prometryne	2,4-bis(isopropylamino)-6-methylmercapto-s-triazine, Geigy.
SD-6623	trimethylsulfonium chloride, Shell Development.
solan	3'-chloro-2-methyl-p-valerotoluidide, Niagara Chemical.

tinued when the seedlings were transplanted to the production fields. Seedbed plots were 4 feet wide x 8, 9, or 10 feet long. Transplants were set in single-row plots 30 to 50 feet long in commercial fields.

Celery varieties: Utah 52-70 selections were planted most commonly; specific varieties are identified in the text. Trials were installed at 4 to 6 weeks after planting to celery seedlings 2 inches or less in height and with up to 5 expanded true leaves. Herbicidal sprays were applied in the fall and winter period, October through January. Plants treated in the seedbeds were grown to market maturity in commercial production fields.

Weed species: Annual grass and broadleaf weed species of the experimental areas and their relative frequencies are listed in Table 2. Individual species of greatest importance in each experiment are listed in the text. The three major infestants and their stages of development at time of herbicide application were: yellow cress, established seedlings to fruiting plants up to 8 inches tall; purslane, established seedlings to fruiting plants from 3 to 12 inches tall; and goosegrass, established and tillering seedlings to fruiting plants from 4 to 12 inches tall.

Herbicidal chemicals and application rates: Herbicides and adjuvants specifically tested recently for celery seedbed use are listed in Table 1 by accepted common name and chemical nomenclature. All herbicide application rates are in terms of active ingredient per sprayed acre. Surfactant rates are in terms of percent commerical product per volume of solution (v/v). Herbicidal solutions were applied broadcast in 50 or 60 gallons per acre of solution, usually in water carrier.

Application equipment: Treatments were applied with hand-carried, CO_2-powered experimental small plot sprayers utilizing several "Tee-Jet" fan-type nozzles on booms to cover the celery seedlings and weeds uniformly.

Response data: Annual weed response was evaluated by periodic visual ratings and observations. Celery response was determined by visual observations and ratings, by transplant weight, and by yield at commercial field harvest. Plants harvested from each plot were divided into standard size classes by commercial packers, and calculated yields in crates per acre were determined on this basis. Data tables summarize the weight of 50 seedlings at transplanting to the nearest 5 grams, plot yields at commercial harvest to the nearest 5 pounds, and

Table 2.--Weed infestants of celery seedbeds.

barnyardgrass	Echinochloa, sp., occasional infestant
crabgrass	Digitaria sp., occasional
goosegrass	Eleusine indica, very common
dog fennel	Eupatorium sp., occasional
Eclipta	Eclipta alba, occasional
mockbishopweed	Ptilmnium capillifolium, common
pellitoryweed	Parietaria floridana, common
purslane	Portulaca oleraceae, very common
spiny amaranth	Amaranthus spinosus, common
yellow cress	Rorippa heterophylla, very common
purple nutsedge	Cyperus rotundus, occasional

calculated yields to the nearest 5 crates per acre.

Residue sampling: Appropriate samples for residue determinations were provided cooperating chemical companies as required for development and registration programs.

Experimental Results

Experiment 11: Herbicides were applied in November, one month after seeding variety 683. Celery seedlings were up to 1 inch tall and the first true leaves were fully expanded. Yellow cress with 2 to 3 leaves and occasional flower buds formed a dense infestation. Purslane with 4 to 5 shoots up to 3 inches tall and goosegrass with tillers 4 to 5 inches long were common.

All herbicidal treatments were judged commercially promising in control of annual grass and broadleaf weeds.

All herbicides reduced celery stand and tolerance (growth) ratings but BV-201 and FW-925 were best tolerated by the crop. Seedling transplant weights did not differ significantly when field set at 6 and 8 weeks after herbicide application. Weight of celery produced per plot and calculated crates per acre yield did not differ significantly among the chemical treatments and the control at commercial harvest. Average values for weed and crop response for selected treatments are reported in Table 3.

Experiment 14A: Celery seedlings, variety Utah 52-70-2-13 SRS, 6 weeks old were treated in October when about 2 inches tall and with 2 to 5 fully expanded true leaves. All weed species were established or fruiting; yellow cress to 6 inches tall, purslane 8 to 12 inches tall and goosegrass to 12 inches tall.

Herbicide/surfactant combinations provided best control of annual weeds. BV-201 and BV-207 controlled yellow cress but not purslane; FW-925 controlled purslane but not yellow cress. Linuron or prometryne, each plus surfactant, controlled both broadleaf species and annual grasses.

Celery seedlings were highly tolerant of all treatments except the linuron surfactant combination, but transplant weights did not parallel the tolerance ratings. Calculated yields in crates per acre did not differ significantly among the treatments. Average weed and crop response values are listed in Table 4.

Experiment 14B: Non-replicated demonstration plots were applied in November to a celery seedbed heavily and uniquely infested with mockbishopweed (Figure 1) . The celery seedlings were about 5 weeks old, with 3 to 4 true leaves and about 1 inch tall. Mockbishopweed ranged up to 2 inches tall and had 4 or 5 leaves. Spiny amaranth and dogfennel were minor infestants and were less than 1.5 inches tall.

BV-201 and BV-207, each at 3 lb/A, had little effect on celery seedlings or annual weeds. FW-925 at 3 lb/A provided partial control of mockbishopweed without effect on celery. Prometryne at 0.5 lb/A plus Atlox 209 at 0.5% affected neither celery nor mockbishopweed but did control the other broadleaf infestants. Linuron at 0.5 lb/A plus Atlox 209 at 0.5% provided almost complete control of all weeds without injuring celery.

Experiment 14C: Drill-seeded Utah 57-70-2-13 SRS celery seedlings were about 5 weeks old and ranged from 1 to 2.5 inches tall and with up to 5 fully expanded true leaves when herbicides were applied in January. Yellow cress 3 to 8 inches tall was flowering, purslane was 4 to 8 inches tall and goosegrass was up to 9 inches tall, tillering and flowering.

Table 3.--Response to annual weeds and celery seedlings to selected postemergence herbicides. (11)

Herbicidal treatment	Weed Control		Celery Ratings		Weight of Transplants	Plot Weight at Harvest	Calculated crates/acre
	Grass	B'leaf	Stand	Toler.			
Control	--	--	100%	100%	535 gm	200 lb	925
solan 2 lb/A	79%	100%	83	75	570	200	890
FW-925 2 lb/A	95	91	95	75	595	200	910
FW-925 4 lb/A	95	83	95	83	500	200	845
BV-201 2 lb/A	83	95	91	95	545	200	865
CDEC 2 lb/A in mineral spirits 50 gpa	100	95	87	79	560	190	820

Table 4.--Response of celery seedlings and annual weeds to selected postemergence herbicides. (14A)

Herbicidal treatment	Annual Weed Control Grass	Y. Cress	Purslane	Celery Tolerance	Weight of Transplants	Calculated crates/acre
Control	--	--	--	100%	605 gm	880
BV-201 4 lb/A	16%	95%	37%	100	770	980
BV-207 4 lb/A	16	100	50	95	650	855
FW-925 4 lb/A	41	20	91	100	515	805
EP-238 1 lb/A	0	12	54	100	750	965
prometryne 5/8 lb/A + Atlox 209 1/2%	62	95	75	91	735	970
linuron 5/8 lb/A + Atlox 209 1/2%	70	100	100	66	650	830

Linuron plus surfactant (Atlox 209 at 0.5%) provided the most effective early annual weed control. Plots treated with linuron or prometryne, with surfactant, were essentially weed-free at transplanting.

Tolerance of celery seedlings to most treatments was acceptable but linuron plus surfactant caused slight injury, especially at the higher rate of both components. These slight effects on the crop were transitory and were not reflected in seedling weight at transplanting or in calculated crates per acre yield at commercial harvest. Table 5 includes crop and weed response.

Experiment 16: Linuron and prometryne were compared at three rates (½, 1 and 2 lb/A) with and without surfactant (Atlox 209 at 0.5%). Drill-seeded Utah 52-70-2-13 F_3 celery seedlings were about 6 weeks old, had 2 to 3 fully expanded true leaves and were up to 4 inches tall. Yellow cress ranged from established seedlings to fruiting plants up to 8 inches tall. Established to many-branched and flowering purslane plants ranged up to 5 inches tall and established and tillering goosegrass plants were up to 4 inches tall.

Linuron was highly significantly more effective than prometryne in yellow cress and purslane control. Use of the surfactant did not improve the performance of linuron, but the surfactant did enhance weed control with prometryne highly significantly. Purslane was more

Table 5.--Celery and annual weed response to postemergence seedbed herbicides. (14C)

Herbicidal treatment	Annual Weed Control Early Grass	Early B'leaf	At Transplanting	Celery Tolerance	Weight of Transplants	Calculated crates/acre
Control	--	--	--	100%	470 gm	890
BV-201 4 lb/A	3%	31%	81%	100	530	920
BV-207 4 lb/A	3	12	78	100	550	885
linuron 5/16 lb/A + Atlox 209 1/2%	28	41	78	100	600	850
linuron 5/8 lb/A + Atlox 209 1/2%	69	62	100	91	585	870
linuron 5/8 lb/A + Atlox 209 1%	72	81	100	84	535	880
prometryne 5/8 lb/A + Atlox 209 1/2%	44	53	94	97	525	860

Fig. 1.—Background, untreated portion of a celery seedbed densely infested with mockbishopweed; Foreground, portion sprayed with linuron at 0.5 lb/A plus Atlox 209 surfactant at 0.5 percent. Photograph taken at 2 weeks after herbicide application.

difficult to control than yellow cress. Increasing application rates improved the effectiveness of linuron slightly and of prometryne moderately. The annual grass infestation was not sufficient for good evaluation but it was noted that both herbicides were commercially effective, especially at the higher rates and with surfactant.

Celery tolerance ratings decreased with increasing rates of linuron application, but the addition of the surfactant did not increase linuron toxicity to the crop. Celery tolerance ratings decreased slightly with increasing rates of prometryne especially with surfactant at the high rate. Celery was highly significantly more tolerant of prometryne than of linuron. Celery seedling weight at transplanting did not differ significantly among the herbicidal treatments. Seedlings tended to be slightly larger in treatments which reduced stand slightly. The herbicidal treatments did not differ significantly in yield at commercial harvest. The data are summarized in Table 6.

Discussion and Summary

The tolerance of celery seedlings to the herbicides tended to decrease as the application rate was increased. Reduced growth of the celery

Table 6.--Summary of broadleaf weed and celery response to postemergence-applied linuron and prometryne. (16)

Herbicidal treatment	Control of Y. Cress	Control of Purslane	Celery Tolerance	Weight of Transplants	Calculated crates/acre
Control	--	--	100%	510 gm	1090
linuron	99**	83**	74	570	1190
prometryne	87	60	97**	550	1250
linuron without Atlox	99	85	75	555	1215
linuron with Atlox	100	81	73	585	1165
prometryne without Atlox	81	53	99*	540	1220
prometryne with Atlox	94**	68**	94	560	1280
Herbicides without Atlox	90	69	87*	545	1215
Herbicides with Atlox	97**	74*	83	570	1220

NB Asterisks indicate adjacent values significantly (*) and high significantly (**) different.

seedlings usually was transitory and seedling weight at transplanting was not affected significantly. Seedlings produced in plots with reduced stands tended to be slightly heavier at transplanting. Differences in calculated crates per acre yield at commercial harvest did not parallel differences in seedling tolerance ratings or in transplant weights.

The performance of BV-201 and BV-207 as compared to FW-925 illustrate post-emergence herbicide requirements. The former, related compounds, controlled yellow cress but not purslane, while the latter herbicide controlled purslane but not yellow cress. Handweeding labor following herbicide treatment was variable and did not always parallel the visual control ratings. More time was required to handweed the plots of chemical treatments which did not control yellow cress; laborers find it difficult to distinguish this winter annual weed from celery seedlings.

Linuron with or without Atlox 209 surfactant and prometryne plus Atlox 209 were the best overall treatments: celery seedlings recovered from slight initial injury, produced normal transplants and attained normal growth and yield in the field. These combinations also provided acceptable to excellent control of small to large annual grass and broadleaf weeds. In these trials, and others, Atlox 209 surfactant seemed to reduce herbicide injury to the crop without sacrificing weed control. All surfactants tested did not perform equally, uniformly or consistently. Additional evaluation of commercially available surfactants with linuron and prometryne would be desirable. Linuron possesses the wider spectrum of weed control activity, but prometryne seems better tolerated by celery seedlings.

Both linuron and prometryne, the latter with added surfactant, would be recommendable for small-scale grower use for annual weed control in celery seedbeds when registration and commercial labelling are completed.

ACKNOWLEDGMENTS

The cooperation of A. Duda & Sons and South Bay Growers, Inc. is appreciated.

LITERATURE CITED

1. Hoffman, James C. 1948. Weeding celery seedbeds with solvent napthas. Univ. of Florida Agr. Exp. Sta. Press Bull. 651.

2. Orsenigo, J. R. 1960. Evaluation of N-(3, 4-dichlorophenyl)-2-methylpentanamide for post emergence weed control in celery. Proc. Florida State Hort. Soc. 73: 184-191.

3. ————————. 1962. Weed control in celery with CDAA and CDEC. Proc. Florida State Hort. Soc. 75: 189-195.