

DRIP FUMIGATION FOR CALIFORNIA CUT FLOWERS

*Husein Ajwa, Tom Trout, Jim Gerik, and Mark Bolda
University of California and USDA-ARS*

The most promising and cost-effective registered chemical alternatives to methyl bromide/chloropicrin (MB:CP) fumigation for production of cut flower and ornamental crops in California are chloropicrin alone or chloropicrin mixed with 1,3-Dichlororopropene (InLine™) applied in combination with metam sodium. Because these fumigants are less volatile than methyl bromide, they can be applied to the raised beds through drip irrigation systems. In drip fumigation, it is critical to distribute the water evenly throughout the field and throughout the target soil treatment zone. Also, chloropicrin and 1,3-Dichlororopropene should not be applied simultaneously with metam sodium to avoid their rapid degradation in the irrigation water. Our research found that drip fumigation with InLine™ (300 lbs/ac) or chloropicrin (200 lbs/ac) followed five to seven days later with metam sodium (40 gal/ac) controlled soilborne pathogens and most weeds and produced yields comparable to those produced with MB:CP. This sequential application of metam sodium after chloropicrin or InLine™ has become the choice of growers in California who are adopting drip fumigation.

Iodomethane (Midas™), a very effective soil fumigant that has similar properties to methyl bromide, can be applied by shank injection or drip fumigation. When registered, several formulations of Midas™ (iodomethane/chloropicrin: 98:2, 67:33, 50:50, and 33:67) can be used for soil fumigation. Midas™ can be applied without metam sodium at 240 lbs/ac or at lower rates if metam sodium is used. Drip fumigation is desirable because workers are not required to be in the field during application. However, successful drip fumigation requires adequate soil preparation, good drip irrigation systems, dependable chemigation equipment, and early soil preparation and bed listing to accommodate longer plant-back time.

Soil Preparation:

As with all soil fumigation, the soil should be prepared and tilled properly. Soil water content should be adequate to initiate weed seed germination and pre-irrigation may be required prior to drip fumigation if the soil is dry. The beds should be free of clods and the plastic tarp used over the bed should not have holes or tears. Embossed tarp should be avoided to reduce volatilization loss of fumigants. Current soil preparation and bed listing practices used after methyl bromide fumigation are generally adequate. Any shanks or chisels should be removed when laying the plastic tarp to avoid creating channels in the soil, which can result in poor water and fumigant distribution in the soil bed. For good water distribution uniformity on steep or hilly grounds, the beds should be directed along the contour lines and the beds should not go uphill more than 4 ft. or downhill more than 8 ft. to avoid poor water distribution uniformity. Poor water distribution will result in poor fumigation. The use of virtually impermeable film (VIF) will enhance weed control in the bed. However, VIF holds fumigants in the soil for longer periods than the standard tarp and longer plant-back time or bed ventilation two weeks before planting may be required (refer to the pesticide label).

Amount of Water:

To achieve good lateral distribution of fumigants in sandy loam soils, 1.5 inch of irrigation water may be needed for to cover 6 to 8 inches horizontally on each side of the tape (fumigants spread more readily through dry soil than wet soil) and 18 inches depth. Table 1 lists the estimated amount of application water per 18 inches of soil depth recommended for drip fumigation of various soils. Although the fumigants move 3 to 5 inches beyond the wetting front,

the best treatment occurs within the wetted area. See Table 1 for recommended amount of water for the various soil types.

Application of fumigants in less than 1.5 inches of water (per treated area) will result in poor fumigant distribution and high volatilization losses that diminish the efficacy to control soilborne pathogens and may result in lower crop yields. In addition, application of fumigants with a small amount of water will result in precipitation of fumigants in the irrigation pipelines if the concentrations exceed their solubility limits (<2000 ppm). Drip fumigation with a larger amount of irrigation water will result in better fumigant distribution in soil and will reduce fumigant volatilization losses by increasing the amount of fumigant in the water phase and decreasing the total air space available for fumigant diffusion in soil. However, excessive amounts of water should be avoided and fumigant concentration in the main line should not be below 500 ppm or fumigant effectiveness might decline (see Table 2 for chloropicrin concentrations). Also, beds can become unstable and collapse with excessive water application amounts, and bed stability may limit the volume or application rate of water that can be applied. In sandy and loamy sand soils, limited lateral water movement may limit fumigant distribution. For these soils, closely spaced drip tape is recommended.

Drip Tape Flow Rate and Spacing:

The drip irrigation systems should provide high water distribution uniformity (DU) – over 90% is achievable. The drip system DU should at least be over 80% for drip fumigation. This will require use of a good system design and operation in which the pressure variation in the drip tape throughout the field is less than 3 psi (ie. from 6 to 9 psi). The system should be free of leaks or clogged emitters, and should be flushed and pressure tested before fumigation. It is imperative to use good quality irrigation components and drip tape. Leaks cause fumigant loss and possibly odor and emissions problems.

Reconfiguration of drip tape spacing may be necessary for good water coverage across the soil bed. For sandy loam soils, one drip tape can cover up to 8 inches on each side using 1.5 inches of water. For narrow beds (<18 inches wide), one tap may be sufficient for drip fumigation. However, two drip tapes are recommended for wider beds (18 to 40 inches wide). A third drip tape may be needed for sandy soils (>90% sand) or if the bed top is wider than 40 inches. Drip tapes with flow rate between 0.5 to 0.67 gpm/100 ft are appropriate for most sandy and sandy loam soils in California (see Table 1). Low flow drip tape is optimum for drip fumigation, but application time becomes inconvenient when using drip tape with low rate drip tapes. High flow drip tape (> 0.7 gpm/100 ft) is not common in California and is not recommended except for soils with high water permeability.

Safety Rules and Chemigation Equipment for Drip Fumigation:

Read and understand the fumigant label and follow County Permit Conditions before starting the fumigation. Know the symptoms and emergency treatments for exposure to the fumigants. Monitor the application system and the field during application.

The fumigant cylinders are pressurized with nitrogen gas and metered directly into the irrigation pipeline or manifold. The meter can be a precision needle valve and flow meter, a needle valve and a scale, or a computer-controlled positive displacement meter. Fumigants are injected at low flow rates and accurate calibration of injection equipment is essential for proper application. Fumigant concentration in the main line may vary from 500 to 1600 ppm, depending on the soil, fumigant type, and water application rate. Refer to the pesticide label for appropriate concentrations. Good fumigant mixing with water in the irrigation pipelines is essential. A static

mixing device is recommended to be installed after the point of injection to thoroughly mix fumigants with water before being distributed into the irrigation system laterals and drip tape.

The irrigation system must have a standard single check valve, low pressure drain, and vacuum relief valve (a “chemigation” valve) upstream of the injection point to prevent possible contamination of the water source by fumigants. The fumigant injector must be equipped with a check valve to prevent water from flowing back into the fumigant tank and an automatic quick-closing valve to stop fumigant injection when water flow is interrupted or loses pressure. The fumigant automatic shut-off valve can be electrically or hydraulically activated and should be normally closed at the injector. For more information on chemigation equipment, refer to the California Department of Pesticide Regulations web site:

(<http://www.cdpr.ca.gov/docs/gwp/chem/chemdevices.htm>) and the Agricultural Commission Office in your County.

Many of the fumigants (including chloropicrin and InLine™) can damage PVC if left in the pipelines. This does not occur during application of the dilute fumigants, but can occur if the lines are not well flushed at the end of the application and the fumigant settles out and accumulates in low points of the distribution system. For this reason, it is critical to flush lines at the end of each application. The required flush water amount can be estimated as three times the volume of the mainline and laterals. Excessive flush should be avoided because it will dilute the fumigants around the drip tape.

Calculations Needed for Drip Fumigation:

- Determine the actual treated (bed) area, and total volume of water, and weight of fumigants to be applied.
- Calculate the time required for application based on the drip tape flow rate.
- Determine the fumigant application rate and concentration in irrigation water.

Table 2 shows chloropicrin concentrations as a function of application rate and water volume. A similar table can be prepared for InLine™ (one gallon weighs 11.2 lbs or 6.57 lbs 1,3-D and 3.73 lbs chloropicrin). Fumigant concentration in water can be calculated as follows:

Chloropicrin: ppm chloropicrin = 119826 x (? pounds chloropicrin/ ? gallons water)

InLine™: ppm (chloropicrin + 1,3-D) = 87872 x (? pounds InLine™/ ? gallons water)

Below 500 ppm, the efficacy of chloropicrin and InLine™ to control soilborne pathogens may become insufficient. Also, because the solubility of chloropicrin and 1,3-D in water is less than 2000 ppm at 20°C, exceeding 1500 ppm may result in precipitation of these fumigants in the irrigation pipelines. Metam sodium (or metam potassium) is water soluble and the generation of the active ingredient methyl isothiocyanate (MITC) occurs in the soil after metam application. However, a minimum of one inch of water is recommended for the sequential application of metam to sandy loam soils.

Table 1. Estimated water amount needed to treat 18 inches of soil depth using two drip tapes. Application time and water volume were based on 30 inches average bed width (50 inches center-to-center).

Soil type	Amount of application water Inches (gallons) ^a	Drip tape flow rate (gpm/100ft)	Application time using 2 tapes (hours)	Comments
Fine sand and loamy fine sand	1.2 (19,551)	0.5 – 0.67	3.1 - 2.3	Pre-irrigation with one inch of water is needed
Sandy loam and fine sandy loam	1.5 (24,439)	0.5 – 0.67	3.9 – 2.9	Minimum of 1.2 inches is recommended
Sandy clay loam and loam	2.0 (32,586)	0.2 – 0.45	13.0 – 5.8	Split application for low flow drip tape
Clay, clay loam, and silty clay loam	2.4 (39,103)	0.2 – 0.45	15.6 – 6.9	Soils are not common in cut flower production

^a One broadcast acre-inch of water is 27154 gallons. One bed acre-inch of water is 16293 gallons.

Table 2. Chloropicrin concentration (parts per million) during drip application

Gallons of water per acre	Pounds of chloropicrin (without emulsifier)															
	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300
19000	946	1009	1072	1135	1198	1261	1324	1387	1451	1514	1577					
20000	899	959	1019	1078	1138	1198	1258	1318	1378	1438	1498	1558				
21000	856	913	970	1027	1084	1141	1198	1255	1312	1369	1427	1484	1541			
22000	817	871	926	980	1035	1089	1144	1198	1253	1307	1362	1416	1471	1525		
23000	781	834	886	938	990	1042	1094	1146	1198	1250	1302	1355	1407	1459	1511	
24000	749	799	849	899	949	999	1048	1098	1148	1198	1248	1298	1348	1398	1448	1498
25000	719	767	815	863	911	959	1007	1054	1102	1150	1198	1246	1294	1342	1390	1438
26000	691	737	783	830	876	922	968	1014	1060	1106	1152	1198	1244	1290	1337	1383
27000	666	710	754	799	843	888	932	976	1021	1065	1110	1154	1198	1243	1287	1331
28000	642	685	728	770	813	856	899	941	984	1027	1070	1113	1155	1198	1241	1284
29000	620	661	702	744	785	826	868	909	950	992	1033	1074	1116	1157	1198	1240
30000	599	639	679	719	759	799	839	879	919	959	999	1038	1078	1118	1158	1198
31000	580	618	657	696	734	773	812	850	889	928	966	1005	1044	1082	1121	1160
32000	562	599	637	674	711	749	786	824	861	899	936	974	1011	1048	1086	1123
33000	545	581	617	654	690	726	763	799	835	871	908	944	980	1017	1053	1089
34000	529	564	599	634	670	705	740	775	811	846	881	916	952	987	1022	1057
35000	514	548	582	616	650	685	719	753	787	822	856	890	924	959	993	1027
36000		533	566	599	632	666	699	732	766	799	832	865	899	932	965	999
37000		518	551	583	615	648	680	712	745	777	810	842	874	907	939	972
38000			536	568	599	631	662	694	725	757	788	820	851	883	914	946
39000			522	553	584	614	645	676	707	737	768	799	830	860	891	922
40000				539	569	599	629	659	689	719	749	779	809	839	869	899
41000				526	555	585	614	643	672	701	731	760	789	818	848	877
42000					542	571	599	628	656	685	713	742	770	799	827	856
43000					529	557	585	613	641	669	697	725	752	780	808	836
44000						545	572	599	626	654	681	708	735	763	790	817