UF UNIVERSITY of FLORIDA
IFAS Extension

Proper Calibration of Soil Fumigant Application Equipment[1]

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Dosage and Field Application Rate

Calibration of soil fumigant equipment and determination of soil fumigant application rate are two of the most important factors contributing to the success or failure of pest control efficacy and crop production response, yet generate some of the greatest confusion among many researchers and growers alike. Little confusion exists with the calculation or expression of broadcast or overall application rates when the entire field area is to receive fumigant treatment. The real confusion for many exists when the entire area of the field is not treated, as with in-row fumigant applications. When in-row fumigant application rates are expressed as pounds or gallons per acre, it is not instantly clear whether the rate represents the amount of fumigant applied to that part of an acre actually under plastic and receiving an in-row fumigant treatment or the amount applied to an actual acre of mulch-covered, bedded row. Similar problems of interpretation can exist with terminology expressing dosage as fumigant product per gross, net, or plastic acre, or per so many rolls of plastic. For in-row or bedded applications, the generally accepted terminology is per treated acre, i.e., the actual land area under plastic receiving fumigant treatment. For in-row applications in which dosage is expressed per treated acre, it is relating the area of treated land and not total cropland covered. Considering application rates as the broadcast equivalent per row acre of mulched covered bed may help minimize such confusion. In this terminology, the broadcast rate is actually applied to the area treated, i.e.,

the area under or delimited by the plastic. The diagram and description of Figure 1 may also help to clarify application rate terminology.

Once dosage or application rate is clearly defined, the next step in the calibration process is to determine how to dispense the fumigant within the treated area as the application equipment progresses through the field during application. Errors occurring at this stage of the calibration process can result in fumigant rates that are low and ineffective, or they can result in over-application, which is more costly, unnecessary, and potentially environmentally hazardous.

Factors other than dosage that are critical to the overall soil fumigant application process include determinations of treatment band or swath width, tractor speed, and flow meter calibration.

Flow Meter Calibration

All soil fumigants, like methyl bromide, chloropicrin, and 1,3-dichloropropene (Telone), are liquids under pressure, and volatilize to gases when exposed to the atmosphere. They are typically manufactured and distributed in pressurized cylinders. As an inert gas, nitrogen is used to maintain constant pressure to the fumigant cylinder to ensure a constant flow of the fumigant from the cylinder to the metering devise during application. In-line valves

Row Middles

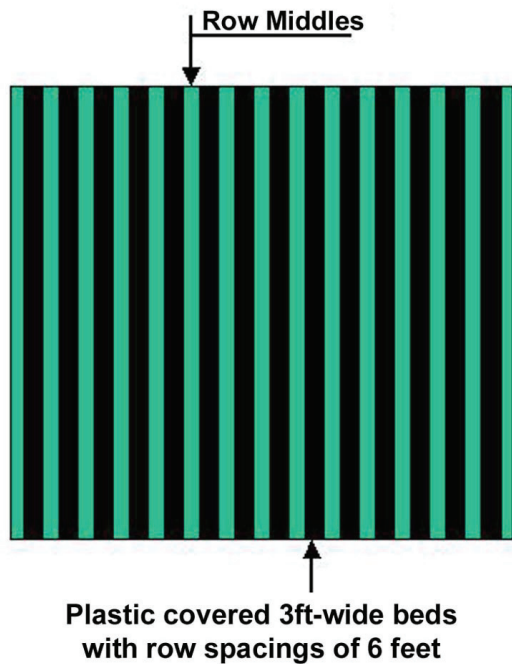**Plastic covered 3ft-wide beds
with row spacings of 6 feet**

Figure 1. A vegetable field composed of plastic-mulch-covered rows and uncovered row middles in which the total area of the block is 1 acre (43,560 sq ft) in size. If the plastic-covered rows are 3 feet wide and the row spacing is 6 feet, then the field area under plastic receiving fumigant treatment is actually only one half acre in size or 7,260 linear feet of row. Assuming a maximum broadcast application rate of 350 lb/a, then only 50% of the acre will receive fumigant treatment, and the amount of fumigant applied within the block or acre of field is 175 lb/a. The correct expression of application rate for this scenario is 175lb/a and/or 350 lb/treated acre. "Treated acre" means the area of actually treated land and not the cropland covered.

The broadcast equivalent of this in-row application is also expressed as 350 lb/a or 350 lb in 14,520 linear feet of row 3 feet wide.

downstream of the fumigant cylinder are then used to actually control the delivery rate of the fumigant to and thru the flow meter.

For most soil fumigant metering systems, a tapered flow tube and float needle are used. The tapered flow tube is configured with a tapered throat leading to a tube constriction, while the exit from the constriction is smooth and elongated. As with any venturi or tapered flow tube, only so much liquid up to a maximum defined as 100% flow, can be forced through the constricted zone of the tube per unit time, regardless of pressure. The maximum or 100% flow rate of the fumigant liquid is, therefore, directly proportional to the cross-sectional area of the smallest passage within the flow meter.

Most of the fumigant flow meters available today are calibrated for water, and not fumigants. Different size flow meters are commercially available but most only allow a maximum 100% flow rate in the range of 1 to 3 gallons of water per minute. Regardless of size or discharge capacity,

the sole function of the meter is to act as a simple gauge to indicate the percentage of maximum flow (0-100%) discharging from the meter. **For calibration purposes then, applicators must first know whether the flow meter is designed for water and the maximum 100% flow capacity of the meter.** This information is usually placarded directed on the exterior housing or within the front window of the flow meter.

Factors other than flow tube size can effect a liquids actual flow rate through the meter. These factors include the liquids viscosity, density, and pipe friction. Friction and viscosity are drag forces reducing flow, and are typically small and inconsequential. Density of the fluid is its weight per unit volume, often expressed in units of pounds per gallon or grams per mil. For example, the density of water is 8.345 lb per gallon (Table 1). As Table 1 illustrates, the density of the various fumigants used today in commercial agriculture are all considerably heavier than that of water, particularly that of methyl bromide and chloropicrin. **All fumigants that are denser, i.e., heavier than water per unit volume, will move through a flow meter more <u>slowly</u> than that of water.** As a result, flow meters calibrated for water <u>must be corrected</u> to account for the reduced maximum 100% flow capacity of the meter for the heavier fumigant compounds. To determine the flow meter correction factor, applicators must know the density of the fumigant in order to calculate the fumigant's specific gravity. Information regarding the density or weight of the fumigant can be found in Table 1 or directly on the pesticide label on the fumigant container.

The specific gravity of a fumigant liquid is a ratio of the density of the liquid to the density of an equal volume of water. As a ratio of densities, it is a relative measure with no units associated with it. For example, the density of water is 8.345 lb per gallon. If the density of methyl bromide is 14.4 lbs per gallon, then the specific gravity of methyl bromide is 1.726 (Density$_F$ / Density$_W$; i.e., 14.4 lb per gallon divided by 8.345). Methyl bromide is a very dense liquid and is approximately 172.6% heavier than water. All soil fumigants have different densities (specific weights) and are heavier than water. In general, the denser a liquid is, the higher its specific gravity, and the more slowly it will flow through a flow meter compared to water. Because of the differences in specific gravity of the various agricultural fumigants, the capacity of the flow meter, typically expressed in gallons per minute, must be corrected according to Equation 1 where specific gravity is the density of the fumigant divided by the density of water. Figure 2 illustrates the actual flow meter correction factors for reduced 100% maximum flow capacity for various fumigants based on the specific gravity

of the fumigant. All values are less than 1, indicating that maximum flow capacity is reduced. An example from figure 2 shows that the maximum 100% flow capacity of a flow meter calibrated for water is reduced by 28% (1.0 minus 0.72) when a heavier fluid such as methyl bromide is passed through the meter.

Equation 1: Calculation of a flow meter correction factor from water to a denser liquid.

Correction Factor = 1 / square root of the specific gravity of the fumigant liquid

Example problem: A certified applicator wants to apply 1,3-D using a flow meter calibrated for water. The 100% maximum flow rate of the meter for water is 2.43 gpm. What is a) the specific gravity of 1,3-D; b) flow meter correction factor; and c) new 100% maximum flow capacity of the meter for the heavier 1,3-D.

$$CF = \sqrt{SG_F} \quad (1)$$

Solution: The density or weight of 1,3-D is 10.2 lb/gal and for water it is 8.345 lb/gal. The specific gravity of 1,3-D is 1.218 (10.2 / 8.345). The correction factor for 1,3-D is calculated according to equation 1 as [1 / square root (1.218)]. The correction factor is 0.906, meaning that the flow of 1,3-D is 906 % of the maximum flow capacity of the meter for water (2.43 gal/min). The corrected 100% maximum flow capacity for 1,3-D is, therefore, 2.20 gallons per minute (0.906 x 2.43).

In some instances, the fumigant flow meter in field use is already calibrated for measuring flow for a specific fumigant such as methyl bromide, and not water. When this is the case, the maximum 100% flow rate for the meter must first be converted from the fumigant it is calibrated for to water (use equation 2), and then from water to the fumigant that is to be applied in the field (use equation 1). The correction factor for adjusting the flow of a meter calibrated for a heavier fumigant liquid with a specific gravity greater than that of water is calculated according to Equation 2.

Equation 2: Calculation of a flow meter correction factor from a denser fumigant liquid to water.

Correction Factor = Square Root of the Specific Gravity of the Fumigant Liquid:
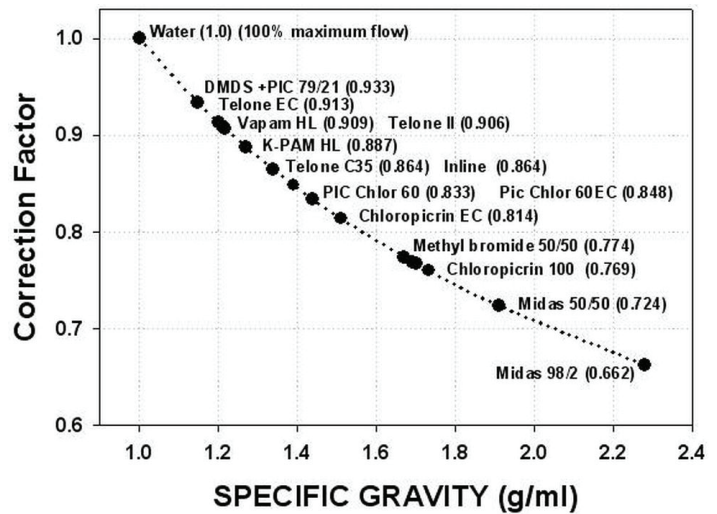
$$CF = SG_F \quad (2)$$

Figure 2. Flow meter correction factors for adjusting 100% maximum flow rate capacity of a meter calibrated for water and applying a denser fumigant with a specific gravity greater than water.

Example problem: A certified applicator wants to apply 1,3-D using a flow meter calibrated for methyl bromide. The 100% maximum flow rate of the meter for methyl bromide is 1.80 gpm. What is a) the correction factor for flow of methyl bromide to water; b) the 100% maximum flow capacity for water; c) the specific gravity of 1,3-D; d) flow meter correction factor for water to 1,3-D; and e) the new 100% maximum flow capacity of the meter for the heavier 1,3-D.

Solution: The specific gravity of methyl bromide is 1.73 (14.4 / 8.345). The correction factor for methyl bromide to water according to equation 2 is 1.3153 (i.e., the square root of 1.73). The corrected flow rate for water is 2.37 gpm (1.3153 x 1.8 gpm). The density or weight of 1,3-D is 10.2 lb/gal and for water it is 8.345 lb/gal. The specific gravity of 1,3-D is 1.218 (10.2 / 8.345). The correction factor for 1,3-D is calculated according to equation 1 as [1 / square root (1.218)]. The correction factor is 0.906, meaning that the flow of 1,3-D is 90.6 % of the maximum flow capacity for water (2.37 gal/min). The corrected 100% maximum flow capacity for 1,3-D is, therefore, 2.15 gallons per minute (0.906 x 2.37).

Tractor Speed Calibration

Careful and precise assessment of tractor ground speed is also very important for accurate calibration of soil fumigant application in the field. If a tractor-mounted radar system is installed, ground speed determinations can be acquired directly from the radar unit. For fumigation equipment without radar, determination of ground speed requires a test course and a stop watch. For the test course, measure and flag a 100-ft-long interval in the field and record

the time for the application equipment to travel the 100 linear feet. Ensure that the test course reflects average soil conditions within the field. Repeat the process at least twice under actual in-field conditions, ensuring identical transmission and tractor RPM settings and tractor loads for all test runs. Take the average of the travel times for all test runs. Tractor speed in miles per hour can then be calculated according to equation 3:

Equation 3:

Tractor Ground Speed (MPH)=

{(60x60x test course) / Seconds} / 5280

or [68.2 / Seconds] (3)

Treatment Width

For broadcast applications where the entire land area is treated and plastic mulch is not used, the treated width is the product of the number of injection shanks or chisels times the distance between chisels. For in-row applications, this distance is the cumulative width of the number of beds simultaneously treated at the time of soil fumigation. For example, if a bed measures 3 feet wide at its base, and 3 beds are treated simultaneously, then treatment width is 9 feet.

REQUIRED INFORMATIOM FOR SOIL FUMIGANT CALIBRATION

Seconds to Travel 100 feet	= _____ seconds
68.2 divide by Seconds	= _____ MPH
Broadcast Rate Per Acre or Per Treated Acre*	= _____ lbs. / acre
Treatment Width (under plastic)	= _____ feet
Corrected Maximum 100% Flow of Meter	= _____ lbs. / min.

CALCULATION STEPS:

Speed (mph x 88)	= _____ ft. / min.
Ft. / min. x Treatment Width	= _____ sq. ft. / min.
Sq. ft. / min. divided by 43,560 sq. ft. / acre	= _____ acres / min.
Acre / min. x Broadcast Application / acre	= _____ lbs. / min.
Lbs. / min. divided by 100% flow of meter	= _____ FLOW METER SETTING

* Ensure broadcast application rates in gallons per acre are properly converted to lbs/acre using the products density or specific weight (see Table 1).

Table 1. Density, specific gravity, and correction factors (as a percentage of maximum water flow) for converting the flow of a specific fumigant through a flow meter designed for water.

Fumigant	Density (lb /gal)	Specific Gravity (g/ml)	Conversion Factor (100% flow rate vs. water)
[2]Methyl Bromide (98/2)	14.4	1.732	0.760
Methyl Bromide (67/33)	14.2	1.702	0.763
Methyl Bromide (50/50)	13.9	1.67	0.774
Chloropicrin	14.1	1.692	0.769
Chloropicrin EC	12.58	1.51	0.814
Telone® II	10.2	1.218	0.906
Telone® EC	10.1	1.20	0.913
Telone® C-17	10.6	1.27	0.887
Telone® C-35	11.2	1.34	0.864
Inline®	11.2	1.34	0.864
Pic- Clor 60®	12.1	1.44	0.833
Pic- Clor 60 EC®	11.8	1.39	0.848
K-PAM® HL	10.6	1.27	0.8874
Vapam® HL	10.1	1.21	0.909
DMDS (Paladin)	8.85	1.06	0.972
DMDS (PaladinEC)	8.84	1.06	0.972
DMDS +PIC (79/21)	9.6	1.148	0.933
DMDS +PIC EC (79/21)	9.6	1.148	0.933
TE3	10.36	1.242	0.878
Water	8.345	1.0	1.0

[2]Formulation representing 98% methyl bromide and 2% Chloropicrin by volume.