Adapted application of pesticides to the growth of a greenhouse tomato crop

[1]Medina Anzano, R.; Sánchez-Hermosilla López, J. ; [2]Gázquez, J. C.; Agüera Vega, F.
Departamento de Ingeniería Rural, Universidad de Almería, Ctra. Sacramento s/n,
E-04120, Almería, España, Tfno. +34 950 015107, e-mail: jusanche@ual.es
(1)Fundación para la Investigación Agraria en la Provincia de Almería (FIAPA)
(2)Estación Experimental "Las Palmerillas"(CAJAMAR)

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Abstract

For the calculation of the pesticide-application volume in a greenhouse tomato crop, four spray tests have been made in different states of crop growth. For this, the spray tests were conducted sequentially with three application volumes for each growth stage. The tracers used were tartrazine, indigo carmine, and patent blue. For the characterization of crop canopy, the evolution of its growth were studied, measuring LAI (Leaf Area Index), which ranged from 0.68 and 3.16 $m^2 \cdot m^{-2}$, and the geometric parameters that define the volume of the vegetation, in order to calculate the TRV (Tree Row Volume) and UCR (Unit Canopy Row). The tests were made with a vertical boom sprayer equipped with a variable number of flat fan nozzles, depending on the height of the crop. LAI was used to calculate the theoretical application volume applying the method of the optimal coverage, spraying the theoretically optimal amount, in addition to 33 % more and 33% less. The deposition was measured at three heights and four depths in the canopy, with four replications per treatment. From the results, the standardized depositions were calculated, based on the amount of tracers per surface ground unit, in addition to identifying the most suitable application volume, based on the standardized deposition and the degree of its uniformity in the canopy. The TRV values calculated were related to those of the application volume that better standardized deposition offered obtaining a regression model with a R^2 of 0.9.

INTRODUCCIÓN

The communication entitled "Towards a thematic strategy for the sustainable use of pesticides", from the European Commission to the European Parliament (2002), encourages agricultural practices that reduce or eliminate pesticide use. In response to this communication the Parliament recommended a 50% reduction in the use of these chemicals over 10 years (Resolution of the European Parliament, 2002/2277(INI)). In this context, correct use of pesticides, as well as the application equipment, becomes necessary. In greenhouses in southern Spain the equipment normally used includes spray guns, using very uneven application rates for similar situations, and achieving irregular distributions of the active material in the different parts of the plant (Sánchez et al., 2001)

For the rational use of pesticides, Manktelow et al. (1997) propose the Tree-Row Volume (TRV), which adjusts the volume applied to the quantity of vegetation in the plot. Furness et al. (1998) recommend an alternative method to the TRV, called the Unit Canopy Row (UCR), proposing this index to calculate application rates. These two indices offer the advantage of providing a measurement of the vegetation volume but do not take into account foliar density.

The fundamental aim of the current work is to improve the application of pesticides in a tomato crop, using a vertical boom sprayer, adjusting the number of nozzles aplplication rate to the characteristics of the existing vegetation at that moment in the crop.

MATERIAL AND METHODS

The assays were made in a Venlo greenhouse, in a crop of tomatoes (cv. Eldiez) transplanted in blocks of perlite. The plants were composed of a single stem with two plants per block. The rows were 2 m apart, for a density of 2 plants·m^{-2}.

The treatments have been carried out using a mobile equipment, developed in the University of Almería and fitted with a vertical boom sprayer which moves at around 30 cm from the crop. This device consists of a platform activated by a electric motor on which the spray system elements are placed, as well as the sensors and control systems required to measure and regulate the variables intervening in the spraying (pressure, flow and travel speed). The nozzles used were uniform flat fan jet (Teejet 95001 EVS) separated by 60 cm, with a working pressure of 5 bar. The forward velocity of the spray machine was changed to give the different application rates.

For adapting the application rates to the plant mass, the necessary measurements were taken to define the overall area, and with this the Tree Row Volume (TRV) and UCR of the plants was measured together with the Leaf Area Index (LAI). These indices were measured for each assay. The measurements made to determine the TRV and UCR were taken at three different heights: 1/3 of the overall height of the plant at a given growth stage. In addition, observations were made concerning depth and weight of the plants at these three heights (Fig. 1).

The LAI measurements were made on three pairs of plants assigned at random in the row where afterwards each assay was performed. The plants were completely defoliated and the leaf area was determined by a planimeter (Delta-T Devices). The LAI was determined at three heights.

The assays were conducted on four different dates corresponding to four growth stages of the tomato plants. For this, the LAI was measured before each assay and the theoretic application rate measured (V_2) according to the la Equation 1. In addition to this application volume, two others were used: V_2, representing 33% greater than V_1; and V_3, 33% less (Table 1).

$$V_2(\mathrm{l/ha}) = \frac{2 \bullet \mathrm{LAI} \bullet D_i \bullet D_v \bullet 10^{7}}{R} \qquad \text{Equation 1}$$

The tracers used were tartrazine (T), indigo carmine (I) and patent blue V (I), at approximately 1000 gr·ha^{-1}, 1500 gr·ha^{-1} and 800 gr·ha^{-1} respectively. The different application rates were applied sequentially on the same plants in order to reduce the variability between assays. First, the lowest volume was applied with the tracer T. The second tracer was added to the sprayer tank, making was a mixture of colorants T and I, and, after their dissolution and homogenization, V_2 was applied. Finally, the third tracer (P) was added to apply V_3. The concentrations of the different colorants were determined by derivate analysis (Berzas at al., 1995) of the spectra of visible light, determined by a spectrophotometer. The spectra of the mixtures were derived and smoothed out by the algorithm of Savitzky-Golay, applying it in intervals of 17 points and adjusting it to a second-order polynomial. Tartazine was measured at the wavelength 456.5 nm, patent blue V to 608 nm, and indigo carmine to 638.5 nm.

The deposition was calculated directly on the leaves of the tomato plants. For this, each plant was divided into three heights and four depths, taking a sample from each of the 12 zones. After the last application, the leaves were placed in zippered polyethylene bags and the samples were stored in darkness to avoid degradation of colorants. The samples were taken from four different plants, considering each plant a replicate.

For the calculation of the leaf area sampled, first, the images of the leaves were taken from a scanner (HP scanjet 5400) at 300 ppp resolution using software UTHS Image Tool V. 3 developed by the University of Texas, Health Science Centre. For the calculations of the quantity of each colorant present in the samples, the leaves were washed with 50 ml of distilled water, which was poured into the same plastic bag used previously to collect the leaves in the greenhouse. The samples, after vigorously shaking for 1 minute to dissolve the colorant, were allowed to settle for another minute and then shaken again for another minute. This solution was analysed with a spectrophotometer (Helios Gamma) between wavelengths 420 and 650 nm, at a rate of 600 nm/min and with a reading interval of 0.5 nm. The analysis methodology used required the spectrum to be kept whole in order to determine (by numerical analysis of the spectra) the concentration of each colorant applied.

RESULTS

The results of the parameters that define the evolution of the vegetal mass are explained in the Table 2. These indicate a strong relationship between the values for volume (TRV and UCR) and for the LAI, given that for the exponential fit between LAI and TRV as well as between LAI and UCR the R^2 value in both cases exceeded 0.95.

The deposition was calculated by normalizing the results to 1000 $gr \cdot ha^{-1}$ of colorant. First of all, a multifactorial analysis of variance was performed to ascertain whether the independent variables, vegetation indices, and the application volumes had an effect on the dependent variable, normalized deposition in this case. The results confirm the hypothesis (P-value<0.002) both for the main effects, individually considered, as well as for the interaction of application rate and vegetation indices.

Duncan's multiple-range test (Fig. 2) was performed between the deposition values and the application volumes found in each assay. Neither in the first nor in the 5th were statistically significant differences (at 95% significance level) detected between the application volumes. In the 2nd assay, there were significant differences between the use of a large and medium volume with respect to a small volume. The results showed that the variations in deposition were not significant in the 12 assays with the least or greatest vegetation mass (Test 1 and 4, respectively). In Test 2, differences were found only between the least volume and the other two, while deposition variations appeared only between the largest and medium volume, as the differences were excessive when compared with the other three assays.

The results suggest that the volumes calculated from the Equation 1 enable the establishment of application rates that provide normalized depositions similar to those that provided the greatest volumes, thereby reducing the environmental impact caused by the pesticide applications. The LAI, as a fundamental parameter for calculating the application volume, presented the drawback of difficult measurement for the farmer, requiring knowledge of the characteristics of the drops generated on using one nozzle or another in addition to evaluating the recovery factor and the number of impacts desirable per unit of leaf surface area.

It should also be highlighted that the trend (Fig. 3) of the mean deposition was to decline exponentially with the increase in the crop's vegetation, regardless of the index used to calculate the quantity of crop vegetation. The trend was determined by averaging the deposition values of each assay. In all cases, the lines of the exponential trends offered $R^2>0.81$. For determining the best application rates, a choice was made of those that, having a deposition in the highest statistical group (Fig. 2), also had a lower variation coefficient and therefore greater uniformity. The results on applying this criterion are shown in Table 3.

The application rate selected, being considered to be the most suitable ones, were related to the parameters that define the developmental state of the vegetation when the spray tests were conducted. The graphs indicate the possibility of adjusting the application rate to a function, if TRV, LAI, UCR and the overall height of the crop are considered, given that the coefficients of fit R^2 were in all cases greater than 0.99 (Fig. 4). The statistical models performed show that the measurements for the vegetation volume adjusted better to reverse first-order polynomial fit, whereas the LAI and the crop height adjusted better to simple linear models. In all cases, the application rate appropriate for each developmental stage of the crop can be correctly estimated, though it would be necessary to carry out more assays in the future.

CONCLUSIONS

The application rates of pesticides can be modelled as a function of the different indices considered to characterize the vegetal mass. The indices considered most appropriate were TRV and UCR, due to the ease with which they could be determined.

It is important to point out that the application volumes to be determined with these indices should not be considered lineally proportional in relation to such indices as TRV or UCR, as in the final stages of the crop it appears that the application volume is overestimated.

The establishment of objective relationships between the depositions at a certain spray volume and the degree of vegetative development of the crop may be a manner of ensuring a more rational use of pesticides. For this, these experiments need to be repeated to develop more robust models of practical application.

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Tables

Table 1. Experimental setting.

Test	nº nozzle	Pressure (kPa)	Nozzle Flow (l/min)	Volume 1 (l/ha)	Volume 2 (l/ha)	Volume 3 (l/ha)
1	2	500	0.50	202	152	101
2	2	500	0.50	290	217	145
4	3	500	0.50	719	540	360
5	4	500	0.50	973	730	487

Table 2. Canopy evolution of crop

Test	dat[1]	Crop height (m)	LAI	TRV (m^3/ha)	UCR (m^3/100m)
1	29	0.80	0.68	2909.38	0.58
2	42	0.89	0.97	3283.47	0.66
3	64	1.60	2.41	5562.78	1.11
4	84	2.10	3.26	9876.85	1.98

[1] days after transplanting

Table 3. Coefficient of variation found in the tests. In bold type selected application rate.

Volume	Test 1		Test 2		Test 3		Test 4	
	V (l/ha)	CV (%)	V (l/ha)	CV (%)	V (l/ha)	CV (%)	V (l/ha)	CV (%)
High	202	73.86	**290**	40.31	**719**	31.73	**973**	44.26
Middle	**152**	41.81	217	61.55	540	43.27	730	48.95
Low	101	52.19	145	95.59	360	46.60	487	47.30

Figures

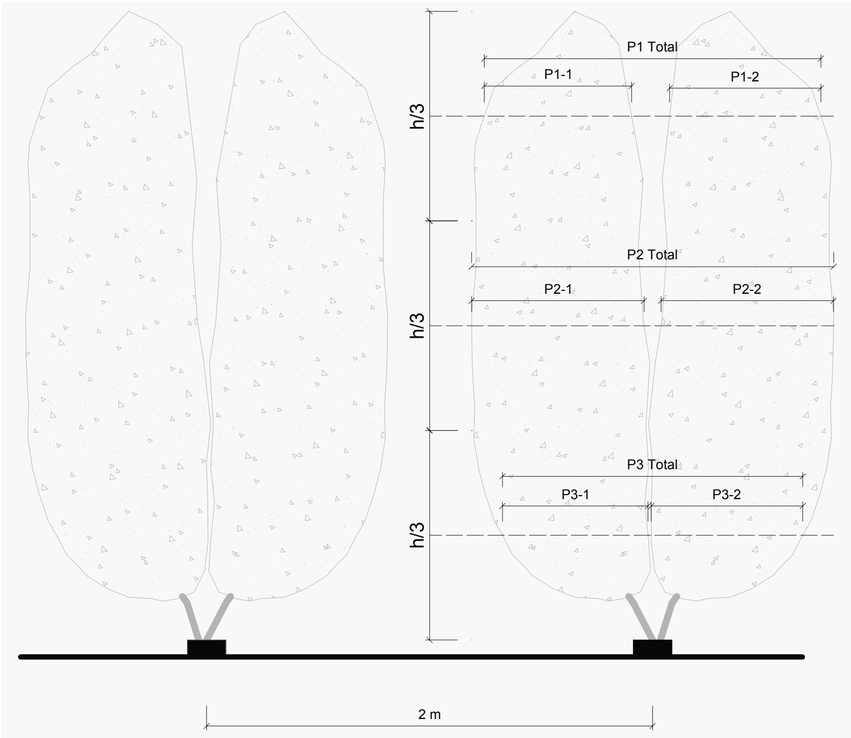

Fig. 1. Sampling areas in the crop

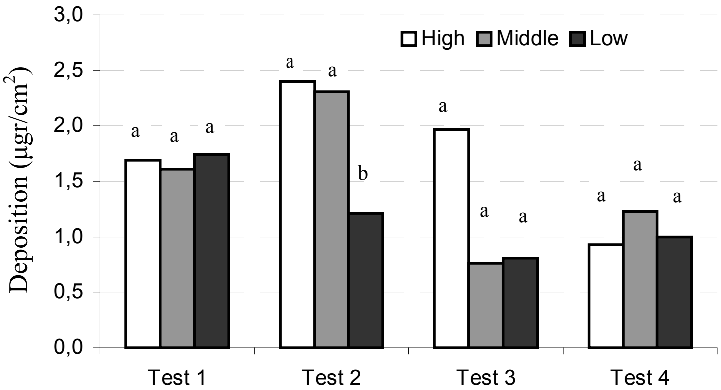

Fig. 2. Mean normalized deposition in four test. Values expressed as µgr/cm^2. For each test columns with a letter in common are not significantly differences at p=0.05

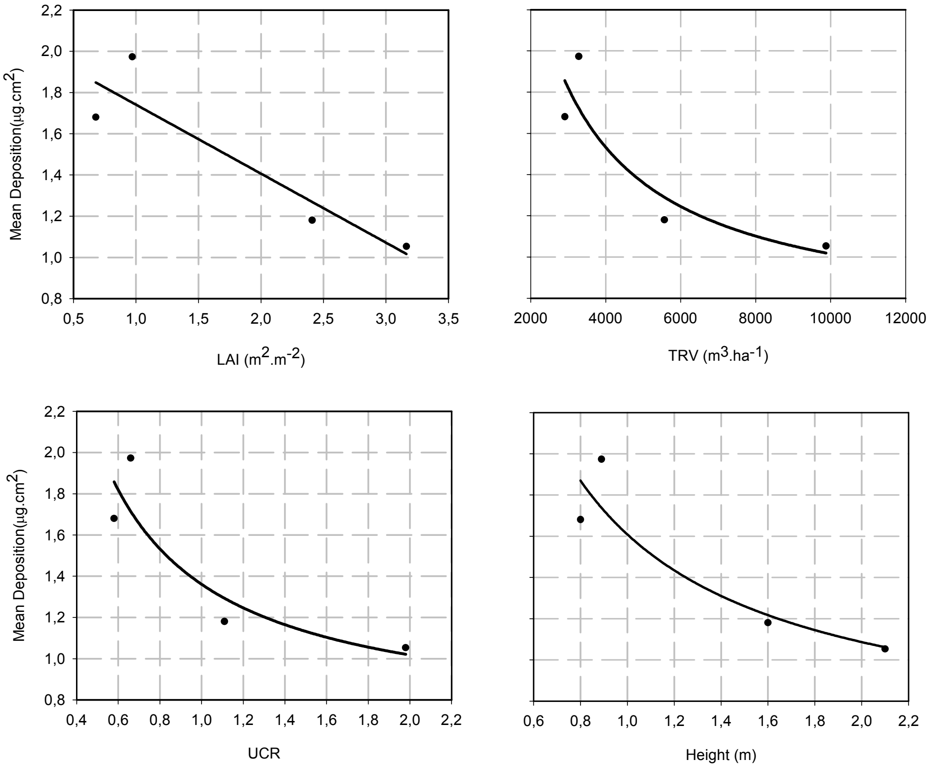

Fig. 3. Mean deposition of three application volumes has been represented in relation with LAI, TRV, UCR and Height of crop.

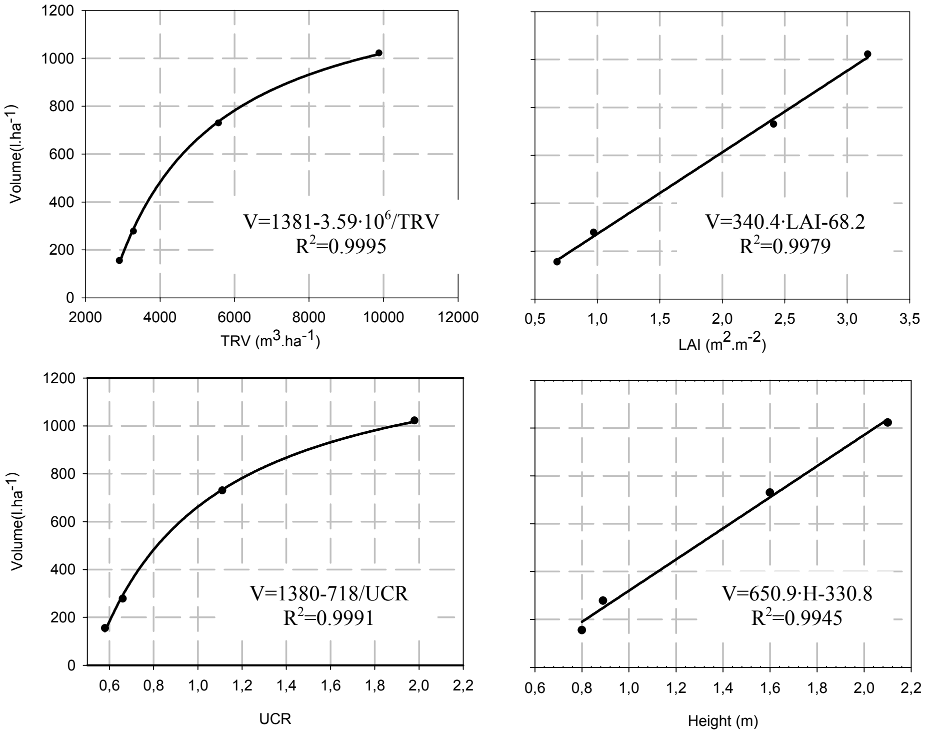

Fig. 4. Application rates versus different indices considered to characterize the vegetal mass.