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Mechanical incorporation in soil of surface-applied pesticide granules

J. H. SMELT, S. VOERMAN and M. LEISTRA

Laboratory for Research on Insecticides, L.I.O., Wageningen

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Abstract

In four field trials surface-applied Mocap 10G granules were incorporated with six types of tractor-mounted soil tillage implements. The distribution of the active ingredient ethoprop (0-ethyl-S,S-dipropyl phosphorodithioate) over four layers of 5 cm thickness was measured. One cultivation with rotary tillers distributed the compound well over the tilled layer of about 15 cm thickness. After one cultivation of sandy loam with a horizontally rotating powered harrow, about 2/3 of the dose was left in the upper layer of 0–5 cm. One cultivation of sandy loam with a powered harrow and one cultivation of humic sand with a spring-tine cultivator, followed by a rotary harrow, incorporated granules to just below 5 cm depth. One single pass with a mounted rotary harrow on humic sand and peaty sand gave a distribution of the compound to about 10 cm depth, but the homogeneity of mixing by this implement might be insufficient.

Introduction

With crop protection in arable farming, the interest in granular nematicides and insecticides is increasing. To get the best result with low dosages it is often necessary to distribute the granules uniformly throughout the plough layer (Miller and Noegel, 1970; Brodie and Good, 1973; Whitehead et al., 1975). The desired uniform distribution with shallow and deep (to 15 cm) incorporation can be attained with one or more cultivations with a rotary tiller (Hulburt and Menzel, 1953; Whitehead, 1974; Rid and Süss, 1959, 1960; Steenberg and Njøs, 1964; Wiersema, 1959). In practice there may be serious objections against rototillage as the top soil is made more sensitive to structure deterioration. In addition, for deep rototillage much machine and labour time is needed and application costs are comparatively high. Therefore it would be attractive if in arable farming the more commonly-used soil tillage implements, such as harrows, cultivators and powered harrows, could be used for incorporating pesticide granules.

Information on the mixing characteristics of soil-tillage implements is rather limited, especially for the more recently developed powered implements. From the results reported by Rid and Süss (1959, 1969), Hulburt and Menzel (1953), and Steenberg and Njøs (1964) it follows that with tined-harrows and tine- cultivators the depth of incorporation was limited. The greater part of the incorporated material remained in the top layer of 0–5 cm, although stated working depth was more than 5 cm. Bromilow and Lord (1975) incorporated Temik 10G granules in a peat soil with 2 types of powered harrows which incorporated the granules to just below 5 cm depth. However, they did not mention the nominal working depth of the implements.

The limited information on incorporation depth attainable and mixing characteristics of commonly used soil cultivation implements made further research desirable. Knowledge about thoroughnes of mixing pesticide granules into the soil is essential for the evaluation of the usefulness of compounds for pest control. In four field experiments, different types of soil cultivation implements were used to incorporate surface-applied Mocap 10G granules. The distribution with depth of the active ingredient ethoprop (0-ethyl-S,S-dipropyl phosphorodithioate) was measured. This compound was not approved for crop protection in the Netherlands. Ethoprop was a suitable tracer, because it could be quickly measured by gas chromatography.

Procedures

Field trials. The trial fields were located near Erica (peaty sand), Anloo (humic sand), Paesens (sandy loam), and Bant (sandy clay loam). The fields were ploughed in autumn or spring. Further cultivations had resulted in a fine-structured and loose top layer of 5 to 10 cm thickness.

The Mocap 10G granules (0.15 to 1.0 mm diameter) were applied with a tractor-mounted Nodet gougis pneumatic granule distributor. The granules were dosed from the reservoir to pipes by a central cam-shaft and blown to the pipe outlets provided with blades spreading the granules. The distance between the pipe outlets was 75 cm. The strips treated were 12 m width. The dosage of approximately 10 g of Mocap 10G granules per m^2 (100 kg ha^{-1}) was applied in April and the beginning of May. Top layers were proper for mechanical cultivations. Weather conditions were dry and sunny. Across the treated strips, 15 m wide strips were tilled with one pass of the implements, giving plots of 12 $\times$ 15 m. Three types of tractor-mounted soil-cultivation implements were used per trial, except for the field near Paesens where two implements were used.

The implements were:

- rotary tiller; provided with 36 L-shaped blades; 1.5 m effective width; tractor-mounted; power-take-off (p.t.o.) driven;
- rotary tiller with tines; 80 curved tines; 1.96 m effective width; tractor mounted; p.t.o. driven;
- horizontally rotating powered harrow; 10 horizontally rotating rotors, each with two tines of 25 cm length followed by a cage roller for depth control; 2.5 m effective width; tractor mounted; p.t.o. driven;
- mounted rotary harrow; 6 rotating bars in V-formation; on the bars blades of 15 cm length located in groups of 4 blades with a distance of 17.5 cm between the groups; 2.5 m effective width; tractor mounted;
- reciprocating powered harrow; two reciprocating bars with 19 tines of 17 cm length; 3 m effective width; tractor mounted; p.t.o. driven;
- spring-tine cultivator; tractor-mounted frame with 13 spring-tines followed by a rotary harrow with two cage rollers; 1.8 m effective width.

Soil sampling. Within a few hours after incorporation, soil samples were taken. The plots of the fields near Erica and Anloo were sampled at 20 points. Soil cores were taken with a cylindrical auger of 4 cm inner diameter to a depth of 20 cm. After dividing the auger lengthwise, the soil from layers of 5 cm thickness was collected separately. The plots of the fields near Paesens and Bant were sampled at ten points. An iron frame (50 cm long and 9.5 cm wide) was pushed vertically into the soil until the top coincided with the soil surface. After this, the soil in the 0–5 cm and 5–10 cm layers inside the frame were collected successively with a guided shovel. Next, two cores of 10 cm length were taken inside the frame with the cylindrical auger and the soil of the 10–15 cm and 15–20 cm layers collected. For each of the incorporation methods two plots per trial were sampled. The soil was bulked per layer and per plot and thoroughly mixed in a chopper. Subsamples of about 0.25 kg were stored for two months in glass jars at −18 °C until analysis. Bulk densities of the layers were determined with 100 cm^3 steel rings. The bulk densities for the layers sampled with the frame were calculated from the total volume and dry weight of the samples.

Chemical analysis. Of the moist soil 30 g was weighted into 200 cm^3 jars, after which 30 cm^3 of distilled ethyl acetate and 15 cm^3 of water were added. The jars were sealed and mechanically shaken for 2 h. After separation of the liquid layers, part of the ethyl acetate was pipetted of. The concentrations of ethoprop in these soil extracts were measured by injecting 5 μl in a Pye Unicam gas chromatograph (Type 795000) equipped with a flame photometer detector. The glass column (1.45 m long and 2 mm inner diameter) was packed with 4 % Carbowax 20 M on Varaport 30 (100/120 mesh). The temperatures were: injector 200°C, column 180°C, detector 200°C. The carrier gas was nitrogen at a flow rate of 40 cm^3 min^{-1}. Retention time was 2.7 min. Standard solutions in hexane with concentrations of 0.01 to 1.0 μg cm^{-3} were made from ethoprop (98.9 % pure) and injected regularly so that the unknown concentrations could be read from standard curves. Moisture contents of the soil samples were determined by drying a 10 g subsample to constant weight at 105 °C. Contents of ethoprop in soil were expressed in mg/kg^{-1} (dry soil). The apparent recovery of the entire procedure was almost 100 %.

Results

Target depth of tillage was at least 10 cm for all tillages in the four fields. With the loamy soils near Bant and Paesens, a loose top layer of only about 6 cm was present. Underneath, these soils were rather stiff and wet and therefore not very suitable for tillages. This restricted the working depth of the implements. Nevertheless,with the rotary tillers part of these stiff layers were cultivated which resulted in a cloddy seed bed. As a result of the cultivations, soil surface level was raised, especially with the rotary tillers. The depths of tillage for the cultivations were measured from the surface of freshly-tilled soil. The ranges of measured depths of tillage are given in Table 1.

From the contents (mg kg^{-1} dry soil) of the active ingredient ethoprop and the bulk densities of the soil (kg dm^{-3}), the amount in each of the layers was calculated. These amounts were summed to obtain the measured dosage. The vertical distribution was characterized by calculating the percentages of the measured dosage found in each of the four layers. The results for the different incorporation methods are shown in Table 1.

The rotary tillers with L-shaped blades or curved tines gave comparatively good distributions of the compound over the tilled layer with all soil types. At the field near Bant, the horizontally-rotating powered harrow gave a less uniform distribution over

Table 1. Vertical distribution of ethoprop in soil after incorporation of surface-applied Mocap 10G granules with different implements.

Implement	Field, soil type	Depth[1] of tillage (cm)	Replicate	Percentage of the dosage in each layer			
				0–5 cm	5–10 cm	10–15 cm	15–20 cm
Rotary tiller	Anloo	10–20	1	33	32	30	5
with L-shaped blades	humic sand	10–20	2	27	31	32	10
	Bant,	13–17	1	28	38	26	8
	sandy clay loam	13–17	2	28	40	26	6
Rotary tiller with tines	Erica,	15–20	1	36	44	16	4
	peaty sand	15–20	2	30	30	27	13
	Paesens,	11–13	1	54	40	6	0
	sandy clay loam	11–13	2	47	45	8	0
Horizontally-rotating	Bant,	10–12	1	65	34	1	0
powered harrow	sandy clay loam	10–12	2	69	29	2	0
	Paesens,	7–9	1	70	30	0	0
	sandy loam	7–9	2	71	29	0	0
Mounted rotary harrow	Anloo,	10–15	1	39	53	8	0
	humic sand	10–15	2	55	39	6	0
	Erica,	10–12	1	71	28	1	0
	peaty sand	10–12	2	50	49	1	0
Spring-tine cultivator	Anloo,	10–15	1	80	18	2	0
followed by a rotary harrow	humic sand	10–15	2	85	15	0	0
	Erica	9–11	1[2]	59	39	2	0
	peaty sand	9–11	2[2]	74	24	2	0
Reciprocating powered	Bant,	6–8	1	75	24	1	0
harrow	sandy clay loam	6–8	2	85	15	0	0

[1] Measured from tilled soil surface.
[2] Two tillages with the spring-tine cultivator and one tillage with the rotary harrow.

Tabel 1. Verticale verdeling van ethoprop in de bodem na inwerken van breedwerpig gestrooide granulaten van Mocap 10G met verschillende werktuigen.

the tilled layers than the rotary tiller with L-shaped blades. Tines, rotating in the horizontal direction seem thus less effective for mixing over the working depth. At first sight the mounted rotary harrow (not p.t.o. driven) shows a rather good distribution of the compound to 10 cm depth in the fields near Anloo and Erica. However, the duplicates at each field differed more than with the other implements, indicating a less homogeneous incorporation. Cultivations with a reciprocating powered harrow on the field near Bant and with a spring-tine cultivator, followed by a rotary harrow on the field near Anloo, resulted in much higher amounts in the 5 cm top layers than in the deeper ones. On the field near Erica two tillages with the spring-tine cultivator followed by one pass of the rotary harrow had a better mixing effect. The distribution of the dosage over the upper two layers was then comparable with that of the mounted rotary harrow.

Discussion and conclusions

With rotary tillers, a uniform distribution of the granules over the desired depth of incorporation may be obtained in a single pass as is shown in Table 1. However, Hulburt and Menzel (1953) and Wiersema (1959) reported that with 2 or 3 passes of a rotary tiller, distribution uniformity was increased. On the other hand Whitehead (1974) found little effect from a second pass on depth or uniformity of incorporation. It is well-known that the intensity of cultivation with a rotary tiller depends on the ratio between driving speed and rotating speed of the rotors. In addition, shape and number of rotating blades or tines affect mixing characteristics (Hams and Collyer, 1963). Differences in these factors may partly explain the discrepancies in literature data.

With spring-tine cultivators, the horizontal distribution of the granules may be irregular. Treated bands near the tine furrows and untreated bands between the tine furrows may alternate which will often make the treatment less effective. After incorporating a ^{32}P marked phosphorus fertilizer into the soil with various types of tine-cultivators and harrows, Rid and Süss (1959, 1960) made such distribution patterns visible on X-ray photographic sheets, placed vertically in the soil.

The soil cultivation implements most frequently used in arable farming such as powered harrow, spring-tine cultivator followed by a rotary harrow and the horizontally rotating powered harrow do not distribute the granules over the nominal working depth. In practice incorporation will be hardly deeper than 5 cm. For applications where only shallow incorporation is sufficient, these three types of implements may be suitable. To establish the most desirable mode of incorporation, pesticide characteristics, soil and climatic conditions, crop and the parasite to be controlled should de considered. Of the more commonly available machines, the rotary tiller is presumably still the most suitable implement to attain a deep and homogeneous incorporation of pesticide granules in soil.

Samenvatting

Mechanisch inwerken van breedwerpig gestrooide pesticide-granulaten in de bodem

In vier veldproeven zijn breedwerpig gestrooide granulaten van Mocap 10G met verschillende typen grondbewerkingswerktuigen ingewerkt. De veldjes werden in laagjes van 5 cm tot op 20 cm diepte bemonsterd en de gehalten van de actieve stof ethoprop (0-ethyl-S,S-dipropyl fosfordithioaat) bepaald met behulp van gaschromatografie.

Zowel de bladenfrees met L-vormige messen als de hakenfrees bleken de granulaten vrij homogeen over de bewerkte laag van ongeveer 15 cm te verdelen (Tabel 1). Bij de rotorkopeg met horizontaal roterende tanden werd ongeveer 2/3 van de toegediende hoeveelheid teruggevonden in de toplaag van 0–5 cm en 1/3 in de laag van 5–10 cm. Met een 2-balks schudeg en een triltandcultivator met dubbele verkruimelaar werden de granulaten tot iets dieper dan 5 cm ingewerkt. Bij deze twee typen werktuigen bleef ruim $^3/_4$ van de toegediende hoeveelheid in de laag van 0–5 cm. Een éénmalige bewerking met een triltandcultivator kan aanleiding geven tot een verdeling van het granulaat in stroken. Een tweede bewerking op dalgrond leek de menging enigszins te verbeteren. Met de messeneg werd op zandgrond en dalgrond een gemiddelde inwerkdiepte tot ca. 10 cm bereikt. Homogeniteit van inwerken kan daarbij gebrekkig zijn geweest.

Van de beschikbare types werktuigen bleken de frezen bij alle vier grondsoorten het meest geschikt om granulaten diep en homogeen in te werken.

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Address

Laboratorium voor Insekticidenonderzoek, Marijkeweg 22, Wageningen, the Netherlands.