

# Development of Controlled Release Phorate Formulations and Their Evaluation for Pest Control and Grain Yield on Sorghum

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Controlled release polymeric formulations of phorate were prepared employing polyvinyl chloride, polystyrene, polymethylmethacrylate, cellulose acetate, ethyl cellulose and polyethylene glycol 6000 matrices. Their phorate release in water was extended upto 21-35 days as compared to 9 days in the case of Thimet 10G, an encapsulated proprietary product. In soil over 40% of unreleased phorate was recovered from the residual polymeric products on the 60th day after application, except in the case of polyethylene glycol 6000. Only 10% phorate on 40th day and 5% on the 30th day were recovered from Thimet 10G and polyethylene glycol 6000, respectively. Apparently, the phorate content of the soil at a given time was a function of its release rate from the polymer. In two field experiments on sorghum crop, polyethylene glycol based product revealed a superior control of *Atherigona soccata*. The performance of other polymers varied in both the experiments. Against *Chilo partellus*, Thimet 10 G was not significantly superior over control whereas the polymeric products were generally superior than even Thimet 10G. All the treatments significantly increased the sorghum grain yield over control. Cellulose acetate in both the experiments and polystyrene and ethyl cellulose in one experiment each gave a significantly better yield increase over Thimet 10G.

**P**horate (0,0-diethyl S-(ethyl thiomethyl) phosphorodithioate) is widely used as a systemic insecticide and acaricide for the protection of a wide variety of crops.<sup>1</sup> In particular, it is applied to soil for the control of soil insects and foliage feeding and plant sap sucking pests. It is highly toxic to mammals and fish; the acute oral LD<sub>50</sub> for rats being 1.6-3.7 mg/kg. Because of its high mammalian toxicity and systemic nature, it is preferably formulated as a granular product.

The environmental hazards associated with toxic pesticides like phorate can be greatly reduced by formulating these as controlled release products. Such products increase pest control efficiency through utilization of reduced quantity of toxicant, reduced toxicity to non target organisms, extended residual activity, masked odour and bitter taste of pesticides, decreased oxidative degradation and reduced pesticide levels in the environment.<sup>2</sup>

Controlled release formulations of dich-

lorvos<sup>3-6</sup>, abate, malathion and naled<sup>7,8</sup> chlorpyrifos<sup>9</sup>, aldicarb<sup>10,11</sup> are already reported. In this study controlled release formulations of phorate have been developed by incorporating it in the matrices of several polymers. The product performance has been evaluated in field on sorghum against the shootfly, *Atherigona soccata* (Rondani) and the stem borer, *Chilo partellus* (Swinhoe).

## MATERIALS AND METHODS

Technical phorate (95%) and Thimet 10G an encapsulated proprietary product, were obtained from M/s Cyanamid India Ltd., Bombay. The polymers polyvinyl chloride (PVC), polystyrene (PS), polymethylmethacrylate (PMM), cellulose acetate (CA), ethyl cellulose (EC) and polyethylene glycol 6000 (PEG) were purchased.

## Formulation analysis

Formulations containing 10% of phorate were prepared by incorporating technical phorate in the

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polymeric matrices<sup>11</sup>. The hard impregnated matrices were broken to obtain 10/30 mesh product.

For analysing phorate content in formulation, weighed samples were refluxed in acetone for 6 h, the undissolved polymer matrices removed by filtration and the filtrates diluted quantitatively with acetone to convenient dilution. Aliquots were estimated for phorate spectrophotometrically<sup>12</sup> with modifications<sup>13</sup>. Phorate extracted from water in water release studies was similarly analysed. The same in extracts obtained in soil release studies was estimated by GLC: detector, flame ionization; column OV-17; temperature (°C) oven 170, detector 275, injection port 250; N<sub>2</sub> flow 38 ml/min; phorate retention time 2.25 min.

#### Phorate release in water and soil

Phorate release in water was studied as per<sup>11</sup> with minor modifications. A known weight (~50 mg) of each formulation was taken in stoppered bottles, 50 ml distilled water added and incubated at 30° C for 35 days. These were shaken once every day and periodically one set of bottles was withdrawn, the contents filtered and the filtrates extracted in chloroform. The chloroform extracts were shaken with anhydrous sodium sulphate, filtered, solvent removed using a rotary evaporator, the residue taken in acetone and analysed. The release of phorate into soil was studied *in vitro*. The same soil in which the field experiments were conducted was used. A known weight (~50 mg) of phorate containing polymers was taken in small capsules made from 5 cm X 5 cm parchment strips. The capsules were placed at 1 cm depth in 10 g soil taken in 2.5 cm dia glass tubes. Water (1.35 ml) was added to provide 40% of water holding capacity of soil and it was maintained during the study. The tubes were incubated at 30 ± 1°C in a BOD incubator. At each sampling (1, 3, 10, 20, 30, 40, 50, 60, 70 and 90 days) one tube was withdrawn under each treatment and phorate content determined separately in the polymer contained in the capsule placed in the soil as well as the soil. One tube of untreated soil as control was taken at each sampling. One parchment capsule soaked in 10 ml acetone for 24 h served as another control.

The capsules containing the phorate polymer

were directly extracted in acetone (10, 10, 5 ml) shaking each time for 3 min. The acetone extract was filtered through 2.5 g anhydrous sodium sulphate, volume made to 25 ml and analysed.

The soil was transferred to 100 ml conical flask, kept soaked in 25 ml chloroform for 1 h and then shaken on a mechanical shaker for 30 min. It was filtered and the soil given two rinsings, each with 25 ml chloroform. The combined extracts were passed through anhydrous sodium sulphate, chloroform removed and the residue taken in 10 ml acetone and analysed.

#### Field evaluation

Two field experiments were laid at the Institute's farm (sandy loam soil, pH 8.3, E.C. 0.50 m, mhos/cm, organic carbon 0.52%). Sorghum, var. CSV-1, was sown late on 26th July and 19th August, 1986, respectively, to ensure heavy infestation of shootfly, *A. soccata* (Rondani). There were 8 treatments including control with 4 replications each and 3 m long rows formed a sub-plot Row to row and plant to plant distances were 75 and 15 cm, respectively. The controlled release phorate polymers and Thimet 10G were applied in seed furrows just before sowing @ 1.0 g/m with the help of graduated glass applicators. Efficacy of various treatments was evaluated on the basis of dead hearts caused by the shootfly maggot upto 21 days after germination. Percentage shootfly damage was calculated. The data were subject to ANOVA<sup>14</sup>

Damage due to the stem borer, *C. partellus* (Swinhoe) was ascertained from a random sample of 10 plants per plot drawn at the time of harvest. Length of each stem was measured and it was split open to record the length of the tunnelled stem to calculate percentage stem tunnelling for each treatment.

The crop was harvested in the first week of December, 1986 in both the experiments. Percentage increase in grain yield due to treatments over control was calculated<sup>15</sup>

## RESULTS AND DISCUSSION

#### Phorate release in water

Phorate release in water from the test formu-

lations is shown in Figure 1. The release from the polymeric formulations was much slower than the commercial Thimet 10G. The minimum period for the complete release of phorate was around 9 days for Thimet 10G, 21 days for PEG, 28 days for CA and EC and 35 days for PVC, PMM and PS based formulations. PEG based formulation released phorate faster than other polymers and PS based formulation released at the slowest rate. Linear release was evident during the first 7 days during which time about 50% of phorate was released from the polymeric products. After this the rate gradually decreased. The release from PVC formulation was faster during the first 21 days after which the rate decreased rapidly. The release from CA and EC was similar; both releasing about 50% of phorate during the first 7 days, 85% during 21 days and 100% in 28 days. The release patterns of PMM and EC were also similar during the first 14 days after which the release from the former slowed down. The release rate from PS was uniformly slow.

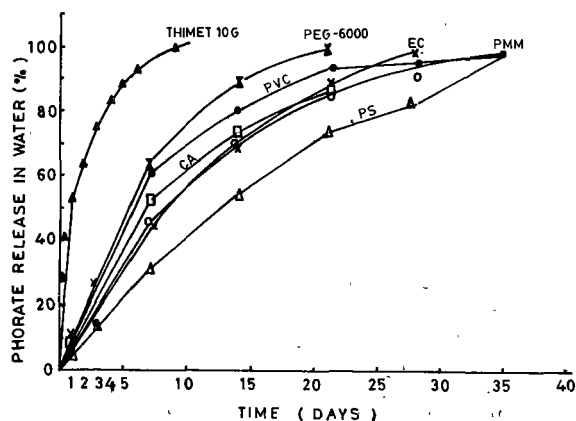


Figure 1 Relative release of phorate from the polymeric products in water

The polymer matrices such as PEG, EC and CA showing faster release are hydrophilic in nature and are easily biodegradable<sup>16</sup>. The hydrophobic polymers with crosslinked matrices such as PVC, PS and PMM showed slower release.

**Phorate release in soil**

On 60th day, over 82% of added phorate was recovered from the polymer itself in the case of PMM, PS and PVC (Figure 2). In the case of PS, over 63% phorate remained in the polymer even after 90 days. In comparison, phorate recovered from CA and EC matrices on the 60th day was only 36-40%. The PEG 6000 matrix contained no phorate from 40th day onward. Thimet 10G which was employed as a reference product, released whole of phorate around 50th day. Amongst different matrices the following phorate release trend was observed.

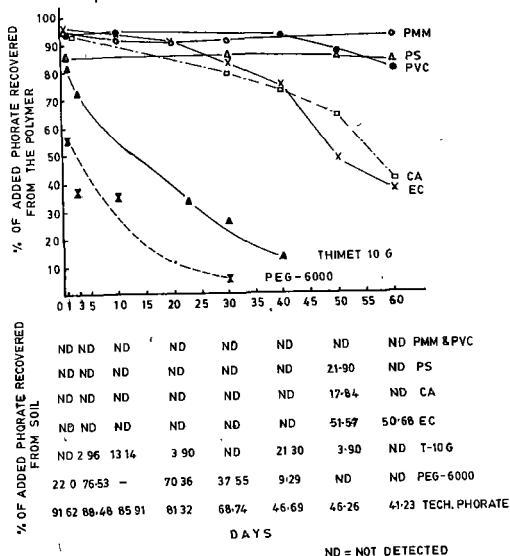


Figure 2 Unrealised and released phorate from the polymeric products in soil

**PEG>Thimet 10G>EC>CA>PVC>PS>PMM**

Phorate recovered from soil revealed that in the case of PVC and PMM, it was not detectable at any stage of the study. In the case of PS, CA and EC, phorate was detected in soil on or after the 50th day. Only in the case of PEG and Thimet 10G, it was detected in soil throughout the study period. It is apparent that during earlier stages phorate was present in soil mostly in treatments showing its faster release.

In soil release studies, an additional control involving direct addition of technical phorate to soil was also maintained. Phorate content in soil from this treatment decreased with time and on the 60th day, nearly 60% of added phorate was lost. It appears that in treatments showing a slower

release of phorate in soil, its non detection may be due to its transformation to other products and in such cases where larger amounts of phorate are released, only a part of it is being recovered and estimated.

### Field performance

The effect of controlled release polymeric products on percentage dead hearts caused by *A. soccata*, percentage stem tunnelling due to *C. partellus* and percentage increase in yield over control are shown in Figure 3. In Experiment 1, PEG treatment showed significantly less dead hearts as compared to the other treatments which were at par with the control (CD 5% = 17.97). In Experiment 2 also, the least number of dead hearts was observed in same treatment though in this case, Thimet 10G treatment was statistically at par with it (CD 5% = 10.55). PS, EC and CA treatments were statistically at par but were superior to the control. PMM and PVC did not differ from the control significantly.

All the polymeric products proved superior to control in reducing the stem tunnelling in both the experiments. In Experiment 1, except EC which was just equal to Thimet 10G, all other polymers were superior to Thimet 10G (CD 5% = 8.24). In

experiment 2, EC, PMM, PVC and PS; CA and PEG; PEG and Thimet 10G; and CA, EC, PMM and PVC were statistically at par (CD 5% = 6.92). In both the experiments, Thimet 10G did not differ significantly from the control.

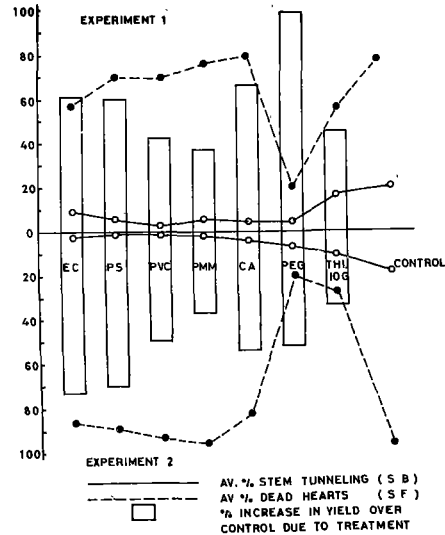


Figure 3 Effect of controlled release polymeric products of phorate on per cent dead hearts caused by shootfly (SF), *A. soccata*; per cent stem tunnelling due to stem borer (SB), *C. partellus* and per cent increase in yield over control.

Table 1 Relative efficacy of different polymeric formulations of phorate for the control of sorghum pests and in increasing sorghum grain yield

| Formulation              | Average dead hearts (%) |               | Average stem tunnelling (%) |               | Average grain field Q/ha |              |
|--------------------------|-------------------------|---------------|-----------------------------|---------------|--------------------------|--------------|
|                          | Experiment 1            | Experiment 2  | Experiment 1                | Experiment 2  | Experiment 1             | Experiment 2 |
| Ethyl cellulose          | 57.53 (53.05)           | 86.14 (68.23) | 9.54 (17.40)                | 3.22 (9.80)*  | 37.56                    | 51.66        |
| Polystyrene              | 70.47 (57.96)           | 89.06 (71.57) | 5.89 (14.07)                | 0.38 (5.07)   | 37.29                    | 50.76        |
| Polyvinyl chloride       | 70.21 (57.27)           | 93.13 (75.07) | 3.13 (9.85)                 | 1.02 (6.83)   | 33.25                    | 44.62        |
| Polymethyl methacrylate  | 76.16 (61.60)           | 95.73 (79.64) | 5.31 (12.50)                | 1.77 (8.25)   | 32.06                    | 40.76        |
| Cellulose acetate        | 79.79 (64.17)           | 82.72 (66.56) | 4.41 (9.82)                 | 4.22 (12.04)  | 38.76                    | 46.09        |
| Polyethylene glycol 6000 | 20.87 (26.63)           | 21.02 (27.08) | 4.49 (11.72)                | 7.45 (16.22)  | 46.52                    | 45.46        |
| Thimet G (Commercial)    | 55.72 (48.33)           | 27.19 (31.13) | 15.91 (23.60)               | 10.67 (19.45) | 33.89                    | 39.96        |
| Control (No treatment)   | 78.74 (65.91)           | 96.87 (84.82) | 20.15 (26.94)               | 18.81 (26.09) | 23.36                    | 29.92        |
| S. Em±                   | (6.13)                  | (3.60)        | (3.00)                      | (2.36)        | 2.95                     | 2.07         |
| C.D. at 5%               | (17.97)                 | (10.55)       | (8.82)                      | (6.92)        | 8.65                     | 6.07         |
| C.D. at 1%               | (24.46)                 | (14.37)       | (12.01)                     | (9.42)        | 11.77                    | 8.27         |

\* Figures in parentheses are transformed values  $\arcsin \sqrt{\text{Percentage}}$

The effect of different treatments was evident from the yield data too. In both the experiments, all the treatments gave a significantly superior yield over control. In Experiment 1, PEG recorded the highest yield followed by CA, both being statistically at par (CD 5% = 8.65). PEG was significantly superior to Thimet 10G. Between other treatments, there was no significant difference. In Experiment 2, CA, PS and EC recorded the highest yield and were statistically at par (CD 5% = 6.07). These were superior to Thimet 10G too. There was no significant difference amongst the other treatments. Amongst different polymers, PS and EC were significantly superior to the other polymers, which were at par.

It appears that the prevailing environmental and other factors during the period of experimentation may be responsible for the differences in the performance of the test formulations. In the present study, due to the different sowing times, the initially prevalent temperature and relative humidity (Figure 4) were different in both the crops, which may have contributed to the differences observed in performance. Studies on the contribution of various physico-chemical and other factors on the release of toxicant from such products are in progress. The present results, however, clearly demonstrate the effectiveness of the formulations due to controlled toxicant release and their general superiority over Thimet 10G.

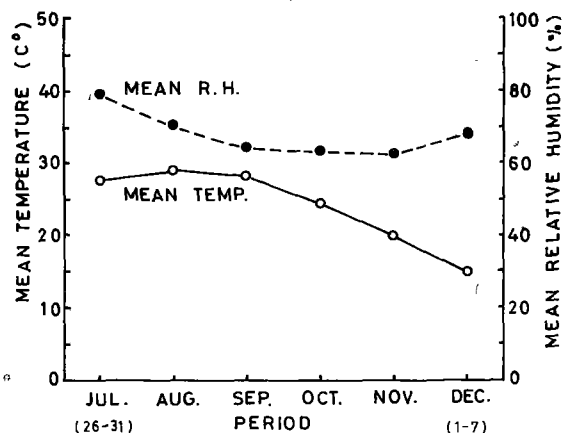


Figure 4 Mean temperature and mean relative humidity during the field evaluation study period (July 26 to December 7, 1986)

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