AN APPRAISAL OF MOCAP AND OTHER SELECTED NEMATICIDES FOR THE CONTROL OF MELOIDOGYNE SPP IN TOMATOES.

BY

STEPHEN SALAMI OKATAHI

B.Sc. (Agric.) Ahmadu Bello University,

Zaria 1968

P.G.D. (Crop Prot.) University of Ibadan

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DECLARATION

The Candidate hereby declares that this thesis is the result of his own individual work and no part has been carried out in collaboration with anyone else except where reference is made to published literature and where assistance is acknowledged.



Candidate's Signature

ABSTRACT

In an attempt to find a substitute for Nemagon five nematicides were tested for the control of root-knot nematodes on tomato. Mocap was quite effective in root-knot control in nursery seedlings but phyto-toxicity was observed when applied at dosages equal to or higher than 10 kg a.i per hectare, the dosage recommended by the manufacturer. Although Nemacur was very effective in the nursery, it has a very high mammalidn toxicity which makes the compound rather dangerous to be recommended now. DD and Basamid were found effective. Basamid however stays too long in the soil at phytotoxic level during the rainy season (more than four weeks). Vydate was the most effective compound in the trial in terms of root-knot control and fruit yield increase; but it has a high oral toxicity, though its dermal toxicity is low. Yield increase ranged from 10% in Mocap, to 87% in Vydate-treated crop at the recommended dosages.

CHAPTER 1

I N T R O D U C T I O N

The Nigerian farmer knows very little about plant parasitic nematodes. Yet this group of animals constitutes a major problem in his crop production, especially in vegetable crops. In all soils where vegetable crops are raised in Nigeria, different species of plant parasitic nematodes are present. The survey of plant parasitic nematodes carried out by Caveness (1968), mainly in Southern Nigeria, showed several different species found in association with various crops. The most common genera he found were Meloidogyne, Helicotylenchus, Rotylenchulus, Scutellonema and Xiphinema. A very important and widespread group are the root-knot nematodes (Meloidogyne spp).

Meloidogyne spp. attack many vegetable crops, causing varying degrees of damage. Bridge (1972) named such vegetables as tomato, carrot, garden egg, melon, cucumber and french bean as most susceptible to root-knot attack, while roots of cabbage, onion, lettuce and hot pepper suffered less attack. In the U.S.A. it is reported that vegetable crops suffer an eleven percent annual loss (equivalent to 270 million dollars or ₦170,000,000) due

to nematodes (Jensen, 1972). Netscher (1970, 1971) showed that the presence of Meloidogyne spp. can be a limiting factor to economic vegetable farming in Senegal. Praquin and Marchand (1970) referred to Meloidogyne spp. and other nematodes as "the most severe technical impediment to vegetable production in West Camerouns". They estimated that when growing tomatoes after tomatoes in the presence of Meloidogyne spp., these nematodes could cause yield reductions of 50 to 70 per cent. Here in Nigeria, Bridge (1972) estimated a 40 per cent yield reduction when plants like tomato, garden egg, cucumber and melon are heavily infested by nematodes. Bos (1978a) however, reported a much more pessimistic figure in respect of french bean raised by Bud-Holland at Kadawa. Yields were only about three tons per hectare, as opposed to an expected eight tons per hectare, due to root-knot infestation.

The problems caused by root-knot nematodes often start at the seedbeds. As the seedlings are attacked, their roots show the characteristic galls and normal development of the root system is prevented. Consequently the translocation of water and nutrients to the aerial parts of the plants is hampered and the plant growth is retarded

(Oteifa and Elgindi, 1962). Bos (1978a) reported that due to poor growth, seedlings of a susceptible cultivar of tomato at Kadawa were being transplanted as late as 10-12 weeks after sowing instead of after the normal period of 3-5 weeks. Plant infestation having started in the seedbeds, continues on the field after transplanting as the nematodes multiply and infest new roots. The situation becomes worse if the fields themselves are nematode infested.

Control measures of root-knot nematodes are based on two principles; that of reducing damage in already infested fields; and that of preventing further spread of the nematodes to non-infested fields. (Anon. 1968; Bos 1978b). To achieve these goals, cultural methods, resistant varieties and chemical sterilization of the soil are being used.

Cultural methods can take the form of crop rotation, fallowing, flooding, use of organic manuring etc. These methods however, have their limitations. The use of crop rotation is limited by the occurrence on the field of a wide variety of susceptible weeds which serve as reservoir hosts (Wilson 1962, Caveness 1965) and by the fact that only few acceptable non-susceptible crops are available for inclusion in the crop rotation cycle (Bos 1979).

Fallow practices, especially bare fallow in combination with repeated turning of the soil may be suitable for certain parts of Northern Nigeria where the long dry season and often very high soil temperatures can kill root-knot nematodes through desiccation and heat; the practice is not easily accepted because the necessary land operations are difficult and expensive.

Flooding as a means of controlling nematodes is effective under certain conditions. Praquin and Marchand (1970) observed that flooding of the soil during the wet season in West Cameroun helped to control root-knot nematodes. Thames and Stoner (1953) found that flooding of rice fields for three months gave practical control of M.incognita for two following crops of vegetables. It has also been observed that fields along the rivers and streams in Northern Nigeria which are inundated for some portion of the wet season are mostly free from root-knot nematodes (Bos 1979) - (as was the case at the Galma and Buruku Irrigation Sites)/which could not produce a single active larva of Meloidogyne when the soil dried up. In temperate climates, Anon. (1968). reported that flooding for 12 to 22 months was required to rid soil of root-knot nematodes. So it can be generally said that flooding

as a means of controlling nematode is limited by the availability of water and the length of time an infested soil remains submerged in water. These are not conditions the farmer can easily manipulate.

The use of resistant varieties of crop plants is regarded as one of the best methods and potentially the most economic and effective ways of controlling nematodes (Anon. 1968 and Taylor 1971). This is particularly true in developing countries where farmers are yet to acquire sufficient skill in handling chemicals. To be of any value however, such a variety must be resistant to the nematode species prevalent in the region or locality concerned, and, also have acceptable agronomic qualities. Several resistant cultivars have been developed for crops such as tomatoes, peppers, french beans, cowpeas, soybeans and sweet potatoes etc. (Sasser and Kirby, 1979). But breaking of resistance in such cultivars has already been reported on several occasions. Netscher (1970) reported the occurrence of an isolate of M.javanica and one of M.incognita capable of breaking resistance in the tomato "Ronita"; Taylor (1975) reported the break-down of a resistant variety of tomato, "Rossol", to Meloidogyne spp. due to the presence of resistance breaking biotypes

(B-races), and Idowu (1979) reported the occurrence of the B-races in a mixed population of M.incognita and M.javanica at Dadin-kowa (Bauchi State of Nigeria) where a resistant tomato variety, Roma VFN was being grown.

This then takes us to the use of chemicals to control nematodes. Taylor and Sasser (1978), are of the opinion that nematicides are the easiest and quickest ways to control plant-parasitic nematodes; the chemicals are an excellent investment if used for production of crops of moderate to high value per hectare. They calculated that: "one dollar used to buy nematicides increases crop value by 4 to 25 dollars or more per hectare". Chemical sterilization of soil alone is by no means the final answer to root-knot nematode control. Oostenbrink (1972) has suggested an integrated control combining the use of Chemicals, proper crop rotation scheme, weeding and resistant varieties - as being the reasonable approach, as long as we are still in search of an ideal chemical which has no practical limitations.

Practical control of plant-parasitic nematodes with nematicidal chemicals started only after 1940 with the discovery of the nematicidal properties of 1,3-dichloro propene - 1,2-dichloropropane mixture. Since then the

development of new nematicides has been intensified so much that we now have a wide range of chemicals from which to choose. The older nematicides are volatile halogenated hydrocarbons which are injected beneath the soil surface. They evaporate to produce fumes which kill nematodes and are therefore called "Soil fumigants". Examples are Methyl bromide, Chloropicrin, DD (1,3-dichloropropane 1,2-dichloropropene) etc. Fumes from soil fumigants diffuse through the soil in the vapour phase. They enter nematode bodies through the cuticle (Taylor and Sasser 1978). Netscher (1971) is of the opinion that the fumes saturate the pores of the soil, and thus kill the nematodes by asphyxiation. Wilson (1962) and Caveness (1965) have recommended the use of DD and Nemagon or DBCP (1,2-dibromo-3-Chloropropene) for soil sterilization in Nigeria. Netscher (1971), working in Senegal, also mentioned EDB (dibromoethylene) stating that DD, EDB and DBCP "are well adapted to nematode control and because of their action asphyxiation will not give rise to nematode resistance to these treatments".

Philis (1974) reported that the root-knot nematode M.javanica Treub on tomatoes was effectively controlled by the nematicides EDB, DD, Di-trapex and Terracur, with

increase in yields. Taylor and Sasser (1978) recommended the use of methyl bromide in seedbeds and nurseries for the control of plant parasitic nematodes, fungi, bacteria, soil insects, and weed seeds. All these recommendations leave no doubt as to the efficacy of the soil fumigants in seedbed applications. But however useful these chemicals are, the peasant farmer in Nigeria may still find it difficult to afford or cope with the requirements for their effective administration. These include, the purchasing of wide polythene sheets or hand applicators; calculation and application of the correct dosage; determination of soil temperature, moisture and tilth required for individual chemicals; the danger of inhaling toxic vapours and the long waiting period of 2-4 weeks before sowing. A less demanding soil fumigant in terms of equipment needed for application is Nemagon in granular formulation. It can be incorporated straight into a well prepared soil making use of ordinary hand hoe. The soil so treated is slightly compressed by foot or otherwise and watered lightly (if necessary) to seal the surface against fumigant escape. The relative ease with which the chemical can be handled or used has made the Agricultural Extension Research Liason Service (AERLS) to reco-

mmend Nemagon 20 to the farmers throughout Northern Nigeria (Extension Guide No. 1). But Nemagon has recently been removed from the market and manufacturing is discontinued. This action was taken because of a reported linkage between male sterility and low sperm counts and exposure to DBCP in factory workers handling the material. There was also the possibility of carcinogenic action of the residues of the chemical in treated vegetable crops (Anon. 1977a). This situation has therefore necessitated a search for a suitable substitute for Nemagon which can be recommended to the Nigerian farmers.

Because of the problems high-lighted above in respect of the soil fumigants, the substitute for nemagon could be sought from the new group of nematicides called the "non-fumigant" nematicides. This group (mainly organophosphates and organocarbamates) comprises chemicals that have contact action and most are known to act systemically in the plant. The non-fumigant chemicals are often applied in granulated forms, and they have other advantages of low phytotoxicity and volatility. But the greatest constraint that may limit their use is their high mammalian toxicity. It is hoped that once a suitable chemical has been identified, their recommendation will be backed

up by thorough education on handling and usage.

The following compounds are used in the trial:

Mocap (Ethoprophos)	O-ethyl S, S-dipropyl phosphorodithioate.
Nemacur (Fenamiphos)	ethyl 4-(methylthio)-m-tolyl-isopropyl-phosphoramidate.
Vydate (Oxamyl)	methyl-N'-dimethyl-N- (methyl-carbamoyl) oxy -1-thioxamidate.
Basamid (Dazomet)	tetrahydro-3,5-dimethyl-1,3,5-thiadiazine-2-thione.

Fumigant:

DD (1,3-dichloropropane;1,2 dichloropropane). This chemical is included in the trial because of its long-standing records and recommendations. But according to recently received information, DD is undergoing a severe scrutiny: the manufacturing of the compound is being halted for health problems among the factory workers (personal information obtained from Dr. Tayo Olowe, Ibadan).

Vapam (Metam-Sodium). Sodium-N-methyldithio-carbamate which is recommended for use in the Western States of Nigeria (Cole-Egharevba, 1977) should have been included in this trial but for the fact that the chemical was not

available at the time of trial, and had not been in the Nigerian market for a long time. (Personal information obtained from Dr. Ogunfowora, Ibadan and Dr. Amosu, Ife).

The objectives of this study are to evaluate the efficacy of the nematicides listed above for the control of root-knot nematodes in seedbeds and assess their use under field conditions; to examine the efficacy of Mocap, which is said to be applicable to the soil at the time of planting, as a possible alternative to Nemagon in Nigeria; to assess damage done by the root-knot nematodes to tomato plants; and to be able to give advice to farmers on the use of nematicides based on economic principles.

CHAPTER 2

Review of Literature

2.1. History of Nematicide Development.

The application of chemicals to the soil to control plant parasitic nematodes solicited the attention of several investigators when it became apparent that these animals were causing economic damages to crops. Kühn (1881) tried a number of chemicals to control the sugar beet nematode, Heterodera schachtii, and found carbon bisulphide most promising. Neal (1889) experimented with numerous combinations of carbon bisulphide, tobacco dust, potassium sulphate, potassium sulphide, sulphur and caustic lime to control root-knot nematodes in Florida. He found tobacco dust to be the most satisfactory of these treatments. Mathews (1919) found the effectiveness of Chloropicrin as a soil nematicide. Johnson and Geodfrey (1932) confirmed this and reported that chloropicrin was a very effective fumigant for controlling the root-knot nematode. The chemical became widely used in the pineapple-growing areas of Hawaii. Richardson and Johnson (1935) worked with methylbromide in glasshouses and found that it has nematicidal properties besides being an insec-

ticide, herbicide and fungicide. The nematicidal properties of 1,3-dichloro propene-1, 2-dichloropropane mixture (DD mixture) was discovered by Carter in 1943, and that of ethylene dibromide (EDB) by Christie in 1945. Ten years later McBeth and Bergeson (1955) discovered the nematicidal action of dibromochloropropane (DBCP). Later in that year Allen & Raski reported the chemical to be effective nematicide after they conducted experiments in 1953 and 1954. DD, EDB and DBCP - Soil fumigants, as they are often called - became the major commercial nematicides in use throughout the world.

The non-fumigant nematicides came later into use than the fumigant types. Whereas the non-fumigants, comprise the organophosphates and organo carbamates, the fumigants, are mainly halogenated aliphatic hydrocarbons. The testing of the non-fumigant compounds against nematodes began in the early 1960s. Sasser (1952) found that demeton[1] used as a soil drench reduced root-knot on tomato and cucumber grown in pots. Helton (1965) demonstrated that

.....

1 = Diethyl 2 - (ethylthio) ethylphosphorothionate + Phosphorothiolate. (Common name: Systox).

dimethoate[2] suppresses root-knot (Meloidogyne hapla) on potato. Other compounds reported to have nematicidal effects include Phorate[3] (Jensen 1966) and Ethoprop[4] (Miller Clark & Perry 1970). Soon after the discovery of the insecticidal properties of carbomyl oxime compounds in the mid 1960s they were tested against nematodes. Examples of compounds in this group with nematicidal action are aldicarb[5] and Oxamyl[6]. Dazomet[7] was first introduced in 1952 by Staceffer chemical company and formulated as a powder ("Pesticide Manual" 5th Edn 1977 p.147). But

.....

2 = O, O dimethyl S - (N-methyl carbamoyl methyl phosporodithioate). (Common name: Rogor Perfekthion).

3 = O, O - diethyl S-(ethyl-thio) methyl phosphorodithioate. (Common name: Thimet).

4 = O - ethyl S, S-dipropyl phosphorodithioate. (Common name: Mocap).

5 = 2-methyl-2-(methyl thio) propionaldehyde O - (methylcarbamomyl) oxime. (Common name: Temik, Carbanolate).

6 = S - methyl 1 - dimethylcarbamoyl-N-(Methylcarbamoyl) oxy) thioformidate. (Common name: Vydate).

7 = tetrahydro dimethyl thiadiazine thione. (Common name: Basamid).

the development of the granule formulation which could be distributed mechanically was reported by Lush, Hans, Hitchman & Levis in 1967. Phenamiphos (nemacur), a highly effective organophosphorus nematicide for both protective and curative applications was developed in Germany by Farbenfabriken Bayer AG and reported in a journal by Homeyer (1971). Burnett and Inglis (1971) confirmed that this chemical gave effective control of root-knot nematodes in tobacco and tomato crops in extensive field tests.

2.2.0 Method of Application.

The following application patterns of nematicides are often used:

Area or overall treatment

Row treatment

Spot treatment

Treatment with gaseous fumigants.

2.2.1 Area or Overall Treatment.

Application of the nematicide to the whole area of a field is known as area treatment. Area treatment is used where maximum control is desired, or when crops are to be planted in rows spaced less than 60 cm apart (Taylor 1971). For this purpose, soil fumigants are usually injected into

the soil at a depth of about 20 cm in parallel lines 30cm apart. Fumes diffuse from these lines, and control is roughly uniform throughout the top 40 cm of soil. An overall treatment can also be accomplished with tractor-mounted power applicators. These applicators are generally used for treating areas of more than 500 square meters. Their essential parts are a device for metering the nematicide and one or more tines for placing it at the desired depth. Metering devices are designed to provide constant pressure on orifices, thus insuring a uniform flow as adjusted to tractor speed (Taylor 1971). For small-scale application of liquid fumigants, hand injectors are available. These deliver nematicides to the soil through a hollow spike. The amount delivered is measured and forced through the spike by means of a hand operated pump. Liquid non-fumigant nematicides are usually diluted to a required concentration and sprayed uniformly over the prepared soil surface. In the case of the granular non-fumigant nematicides, they are generally spread uniformly over the soil surface and then usually incorporated inside to a depth of 10 to 20 cm. (Taylor and Sasser 1978). In the case of Ethoprop "Nematode control is best where the material is incorporated into the top 7 to 15 cm of soil"[1].

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1 = Mocap Crop Bulletin No.174 by the Mobil Chemical Company p.10.

2.2.2 Row Treatment.

Row or furrow treatment is particularly useful where a crop is to be planted in rows spaced 60 cm or more apart (Taylor and Sasser, 1978). Row treatments are used for cotton, tobacco, vegetables and maize (Caveness 1965). Taylor (1971) described it as a very efficient way of using nematicides. The cost is approximately one-half of overall application by comparison (Sasser 1976).

2.2.3 Spot Treatment.

Spot treatments are used where the plants are widely spaced, as in orchards. A single injection of fumigant nematicide produces a spot of treated soil about 30 to 40 cm in diameter in which one plant can grow. The nematicide can be incorporated near the plant base or can be applied by hand applicators (Caveness, 1965; Taylor and Sasser 1978).

2.2.4 Seedbed Treatment with Gaseous Fumigants.

The application of gaseous fumigants like Methyl bromide or Chloropicrin to the soil can not be done by any of the methods described above because of their peculiar characteristics of being in the gaseous phase even at low temperatures ($4^{o}C$). When such chemicals are to be applied to seedbeds or potting soil, the soil is

prepared for treating as if for planting. Then a plastic sheet is placed over the plot with its edges well buried in the soil. A tube from an applicator opens under the plastic. The chemical is placed in the applicator and flows through the tube as the applicator is operated (Taylor and Sasser, 1978). The plastic, or gas-proof sheeting used does not only protect the user from the poisonous gases, but also encourages adequate retention of the fumigants in the soil (Khair and McLeod 1974).

2.3.0 Physical Factors Affecting the Effectiveness of Nematicides.

The physical factors affecting the effectiveness of nematicides that are mentioned in this passage are: Soil type, soil moisture, soil temperature and pH.

2.3.1 Soil Type and Preparation.

The diffusion of volatile nematicides in the soil is influenced by the soil type. Sandy loam soils or soils with low organic and clay contents are the types in which volatile nematicides as well as non-fumigant types are most effective in controlling nematodes (Allen & Raski 1955). Clay particles or excessive organic matter can absorb the nematicide and reduce its dispersion in the soil. The pore spaces in clay soils are relatively small and are

likely to be filled with water which blocks the spread of the nematicide. This results in incomplete fumigation. Clay soils therefore require 20-50% more fumigant than sandy soils for effective treatment (Khair and McLeod 1974). It is known from the work of Hagan (1941), Stark (1948), Wade (1954, 1955) and Call (1957) that carbon bisulphide, ethylene dibromide, and chloropicrin are highly absorbed when they are in contact with dry soil. When the pore spaces are relatively large as in sandy soils, the nematicides applied spread rapidly, hence attention must be given to the problem of sealing the surface to prevent escape of the nematicide into the air above the soil (Sasser, 1976). For most chemicals proper soil preparation is very important for best results. In order to be effective, the chemical must penetrate the entire soil mass to the depth required. The best way to obtain this is to prepare the soil to the consistency of a good seedbed - free from lumps and clods - as a good number of nematodes can hide in them. Root debris or plant residues from the preceeding crops should be removed, otherwise they could form "chimneys" through which the fumigant can escape before it has a chance to become effective (Caveness 1965).

2.3.2 Soil Moisture.

Hagan (1941) has indicated that soil moisture is the most important factor limiting diffusion of fumigant nematicides. As soil moisture increases more soil pores fill with water, which inpedes diffusion of gases, resulting in poor distribution and prolonged retention of the fumigant in wet soils (Khair and McLeod 1974). Conditions of moisture and temperature which are optimum will vary with soil type, nematicide used, and other factors (Sasser, 1976). But talking of general conditions, Caveness (1965) said: 'soil is usually at the proper moisture level for fumigation when it barely retains its shape after being squeezed in a palm of the hand'. Most recommendations call for a soil moisture content above field capacity in sandy soils (Allen 1960; Caveness 1965). In sandy loam or clay loam soils, however, the moisture should not be more than 85% or less than 50% of field capacity (McBeth & Bergeson 1955).

2.3.3 Soil Temperature.

The diffusion of fumigant nematicides also depends on soil temperature. Caveness (1965) suggested that the application of a soil fumigant should not take place if the soil temperature at 15 cm depth is above 29°C. This

is because excessive temperatures cause very rapid dispersion of fumigant gas and control is not achieved. On the other hand, there is a lower limit of temperature beyond which fumigants can not work. Castro and Thomason (1971) showed that EDB is not effective below 10°C. Peachy (1965) said that soil temperature should be above 7°C for the application of DD and above 16°C for EDB and DBCP. Khair nd McLeod (1974) reported an optimum temperature of 21°C for fumigants application.

Soil temperature does not seem to affect the efficiency of the non-fumigant nematicides, as the literature accompanying the various non-fumigant compounds presently on the market is silent over temperature effects. Khair and McLeod (1974) were of the opinion that this group of nematicides could be used to advantage when temperature and soil factors are unsuitable for the application of fumigants.

2.3.4 Soil pH.

pH has no major effect on the toxicity of alkyl halide nematicides, the substances however, do hydrolyse in basic or neutral media (Castro and Belser, 1966). For many non-fumigant nematicides, pH exerts certain effects on their hydrolytic stability. Mocap is very stable in acid

aqueous media from 25°C to 100° and hydrolyses moderately fast in basic medium at 25°C and rapidly at 100°C[1]. Oxamyl in solid form decomposes to inocuous materials in natural waters and in soil. The rate of decomposition is increased by alkalinity, aeration, sunlight and higher temperatures[2]. The rate at which Dazomet (Basamid) breaks down in the soil to methyl isothiocyanate appears to be hastened in soils with low pH (Pesticide Manual 5th Edn p.141). As for Nemacur, Homeyer (1971) gave its hydrolytic stability as follows: 40% degradation after 14 days at pH 2, no degradation after 14 days at pH 7 and half-life of 31.5 hours at pH 11.3 (Pflanzenschutz-Nachrichten Bayer 24/1971, 1 : 50).

2.4. Mode of Action.

The mode of action of nematicides depends on the type of nematicide used. It is known that both fumigants and non-fumigant nematicides dissolve in water at least to some extent and enter nematode bodies through the cuticle

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1 = Mobil Chemical Tech. Bull. on Mocap No. 10-1 Sept., 1973.

2 = E.I. du Pont de Nemours & Co (inc.) Product Development Bulletin on "Vydate" Jan., 1977.

(Taylor and Sasser 1978), but what happens beyond the cuticle depends on the nature of the chemical.

2.4.1 Fumigant Nematicides.

In the case of fumigant chemicals, Castro and Thomason (1971) studied the entry of EDB and DBCP into Aphelenchus avenae, Tylenchulus semipenetrans, Anguina tritici and Caenorhabditis sp., and made several observations. They found that the nematode cuticle is not a barrier to penetration by nematicides which readily enter the body though not by ingestion. Permeation through the cuticle is a dynamic process in which the nematicide concentration inside nematodes rapidly comes to an equilibrium with the concentration in their aqueous environment; the equilibrium concentration of nematicides in the animals exceeds that in the external solutions. Thus, the equilibrium concentration of ethylene dibromide in A.avenae exposed to a 0.53×10^{-2}M solution was found to be 1.34×10^{-2}M, and the animals remain alive for hours under this condition. They also found that there are multiple sites available for the action of any biocide on a living system. In an attempt to explain the toxic action of the alkyl halide namaticides, they showed that at concentrations under 200 ppm, nematodes become quiescent and then die slowly. The slow

death was probably caused by interference of the nematicides with the iron-containing enzymes of the respiratory sequence. At concentrations above 200 ppm, there was contortion of the nematode body and rapid death explained by alkylation at numerous sites within the animal body. Metscher (1971) had a simpler explanation to the toxic action of the alkyl halide nematicides: "when these products (DD, EDB and DBCP) are introduced into the soil, they evaporate slowly and saturate the pores of the soil, thus killing the nematodes by asphyxiation".

2.4.2 Non-fumigant Nematicides.

The non-fumigant nematocides, which are mainly organophosphoros and carbamate compounds, apparently have a different mode of action. Rhode (1960) demonstrated histochemically the presence of an esterase which hydrolysed acetylcholine (the synaptic transmitter) in Paratrichodorus minor*, Pratylenchus penetrans, Xiphenema americanum. Helicotylenchus dihystera and Dorylaimus sp.; and showed that this enzyme is inhibited by organophosphorus insecticides. Lee and Atkinson (1965) reported that Aldicarb,

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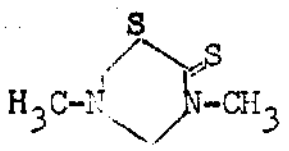
*Formerly Trichodorus christiei

a carbamate derivative rapidly inhibits body activities of juvenile Heterodera and causes enzyme hydrolysis of acetylcholine in Panagrellus. They also found Phorate active against certain nematodes and said: "it seems to act against the cholinesterases of the worm". Kampfe and Dietze (1972) were able to show the inhibition of cholinesterase with systemic nematicides in nematode sections histochemically and found cholinesterase located in the central nervous system. It is generally accepted that the organo-phosphoros and carbamate compounds act in insects by inhibiting the hydrolysis of acetylcholine by the enzyme acetylcholinesterase (Corbett, 1974). From the work of Bunt (1975), on the effect and mode of action of oxamyl and phenamiphos on nematodes in Vitro, he observed muscular contractions, paralysis crinkling and stylet protrusion - indicating poisoning of nerve systems, in all nematodes examined. He concluded that: "the many similarities with the effect of two chemicals in insects and mammals, support the hypothesis that they act upon the enzymes involved in the transmission signal to muscular tissues by transmitter substances, such as acetylcholinesterase".

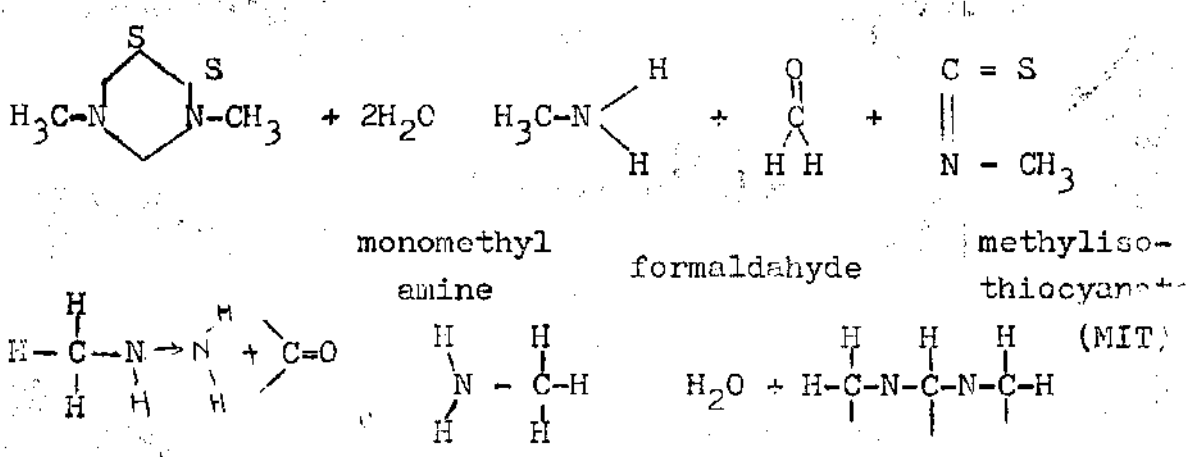
2.5 Properties and activities of nematicides used in the Trials.

2.5.1 Basamid (Dazomet).

Dazomet is the common name approved for the chemical, tetrahydro 3, 5-dimethyl - 1, 3, 5 - thiadiazime-2-thione. It has a structure:



which in moist soil breaks down to various degradation products:



- All these products give the compound a very broad spectrum of activity.

Dazomet was introduced in 1952 by the Umion Carbide Corporation under the trade mark "Mylone", and by Bayerische Anilin und Soda Fabriken AG (BASF) under the trade

mark "Basamid". The solubility of Basamid in water is 1.2 g/litre at 30°C. It is of moderate stability but its stability is sensitive to heat above 35°C, and to moisture.

Dazomet formulations are: dust (850 g a.i/kg) and 'Basamid' granules (950 g and 980 g a.i/kg). Originally dazomet was formulated as a powder, but the need for a product which could be distributed mechanically resulted in the development of a granule formulation (Lush et al. 1967). The chemical is strongly phytotoxic and soil treated with it should not be generally planted until shown to be free of the compound and its decomposition products. This can be by monitoring the germination of Cress seed sown on a sample of the treated soil (Pesticide Manual 5th Edn p.141). High moisture content of the soil and low temperatures tend to prolong persistence of the chemical in the soil. The compound is not recommended for use when the soil temperatures are below 7°C (Lush et al. 1967).

Toxicity to mammals is moderately high. The acute oral LD50 for rats is about 640 mg/kg; the 85% dust is irritant to the skin and eyes of rabbits.

The BASF gave the advantages of Basamid granular as follows: It produces no drift from the wind; it can be spread evenly; the uniformity of application is readily visible; it requires no complicated application equipment; no complicated methods are needed to "seal" the soil; no unpleasant odour during application; no side effects; the gases do not form until the product and the soil are mixed; and very broad spectrum of activity with the standard application rates.

Dazomet is reported effective for the control of nematodes as well as soil fungi such as Pythium, Rhizoctonia, Fusarium, Verticillium and Colletotrichum when incorporated into glasshouse soils at rates of 370 to 400 kg/ha. At these rates it is also effective against wireworms, millipedes and soil insects and suppresses the growth of many weeds (British Crop Protection Council: Pesticide Manual 5th Edn. p.147).

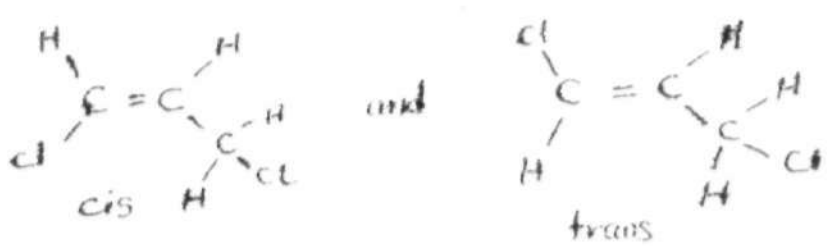
Several workers have used Dazomet to control nematodes on crops like groundnut, onion, carrot, potato, tobacco and tomato, and reported varying degrees of phytotoxicity due to the chemical. Chabra & Mahaja (1976) tried dazomet, aldicarb and phensulphothion to control Pratylenchus coffeae on groundnut (Arachis hypogaea) each at the rate

of 400 kg/ha, he found that in this experiment dazomet was less effective in controlling the nematode than the other nematicides mentioned. A preplant application of 500 kg/ha of dazomet stimulated development of some onion varieties but depressed that of other. Onion planted 5 or 6 weeks after application of dazomet showed stunting, yellowing and shrivelling of leaves though recovered after 2 weeks. Waiting periods of more than 6 weeks were recommended (Greco & Lambert 1977). Shepherd (1975) tested granular dazomet (98%) in tobacco seedbeds in Rhodesia (Zimbabwe). He found the compound not very effective but rather phytotoxic to the seedlings. When Whitehead & Smith (1975) tried to control Heterodera rostochiensis* larvae attacking roots of young potato plants, using dazomet at the rate of 330 kg/ha, he recorded 98% decrease of the larvae population. Also most of the eggs were killed. Dazomet has been successfully used to reduce damages due to root-knot nematodes and fungal attack on tomato plants. Fungi like Pyrenochaeta lycopersici and Colletotrichum cocoides as well as Meloidogyne incognita were controlled resulting in doubling the yield of tomato (Cuany, Lavergne, Clerjean & Noarrisseau 1974). Ogunfowora (1979) also found dazomet at 500 kg/ha

*now Globodera rostochiensis

to be very effective provided sufficient waiting time is allowed prior to sowing in order to prevent phytotoxicity in the seedlings.

2.5.2 DD: Dichloropropene - dichloropropane mixture plus many related compounds. The most active ingredient, dichloropropane, is a halogenated aliphatic hydrocarbon having the following structure:



The product is often referred to by its trade mark 'D.D'. It was introduced by Shell Development Company in 1942 (Pesticide Manual 5th Edn. p. 179). Its first use as a soil fumigant was described by Carter (1943). Pure Dichloropropene is sold as Telone by the Dow Chemical Co.

DD is a clear liquid, with a pungent odour. Its solubility in water at room temperature is low, being about 2 g/kg and it is soluble in hydrocarbon and halogenated solvents. The mixture is stable up to 500^{o}C. It is strongly narcotic but low concentrations cause an irritation of the respiratory tract. Exposure of guinea pigs, rabbits and rats to concentrations of 1,600 ppm for seven hours was tolerated by the first two species ('Pes-

ticide Manual' p.178).

DD is a pre-plant nematicide effective against soil nematodes including root-knot, sting and dagger, spiral and sugar beet cyst nematodes. The mixture is usually applied by injection into the soil or through tractor-drawn hollow tines, to a depth of 15 to 20 cm at 150 l/ha on light soils to 400 l/ha on heavy soils, and soils containing much organic matter. The soil should be in "seed-bed" condition and moisture should be at field capacity before application. The soil surface can be sealed by rolling a water-filled oil drum once over the treated area (Bos, 1978b). Because the chemical is phytotoxic, the soil should be opened up to allow the fumigant to escape. The waiting time is two to four weeks before planting. The waiting time is shorter in light soils, warm soils, and soils of low moisture content. But it is longer in wet or cold soils and in heavy soils.

DD has often been included in trials with other nematicides to control plant parasitic nematodes. Marks, Elliot & Tu (1971) compared 5 nematicides (DD, Vorlex, Dasanit, Furadan and Mocap) for control of root-lesion nematodes (Pratylenchus penetrans) on flue-cured tobacco in Ontario. They found that DD, Vorlex and Mocap produced

higher yields than the others under high nematode population densities. Philis (1974) reported that Meloidogyne javanica Treub. on tomatoes was effectively controlled with DD at 50 litres, EDB at 11.3 litres, Di-trapex at 50 litres and Terracur at 2.5 kg a.i per hectares and, as a result yields were increased. Ogunfowora (1979) tested Nemagon 75, Basamid, Vapam and DD in the nursery and in the field for the control of root-knot nematodes on tomato. He found that DD gave the most effective control resulting in slight root galling and strong vegetative growth, though no significant increase in fresh fruit yield was recorded. In Ghana, Nemeng (1977) found DD as effective as Nemagon and Vapam in controlling M.incognita on a susceptible tomato cultivar. Dandria, Lamberti & Vorlas (1977) in Malta showed DD at 300 l/ha to be the most effective of the nematicides tried against M.incognita. He found that whereas Phenamiphos and Oxamyl attacked the infective larval stage only DD also acted directly on the eggs of M.incognita, hence making it most effective.

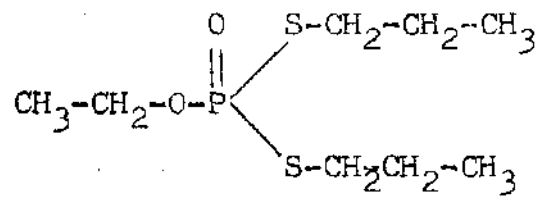
In a trial carried out at Bambey, Senegal, the behaviour of two tomato cultivars, one resistant (Rossol) and the other susceptible (Roma) to Meloidogyne javanica, was

compared on a field infested by the parasite. Before planting the field was treated with different nematicides: DD, Nemagon and Dupont 1410. Of these, only DD was found capable of raising yields of Roma to a level comparable with yields of Rossol (Netscher and Mauboussin 1973).

From the foregoing account, DD is an effective nematicide which can be employed as a seedbed sterilant, and also as a treatment of large fields provided it can be applied properly.

2.5.3 Mocap (Ethoprophos).

Ethoprophos or Ethoprop is the common name approved by the British Standard Institution and the American Chemical Society for Mocap respectively. It was introduced as a nematicide and soil insecticide by Mobil Chemical Company in 1963 under the trade marks 'Prophos' and 'Mocap' (Pesticide Manual 5th Edn. p.248). The chemical structure of the organophosphorus compound is:



O-ethyl SS - dipropyl phosphorodithioate.

The physical state of Mocap is a clear liquid with yellow tint, having a vapour pressure of 0.00035 mm Hg (26°C) and specific gravity of 1.094. The compound is very soluble in most organic solvents, and soluble to 750 mg/litre in water. In terms of stability, it is very stable in acid aqueous medium from 25°C to 100°C, but rapidly hyrolyses in basic media at 25°C. Mocap is commonly formulated as an emulsion concentrate (700 g a.i/l) or as granules (100 or 200 g a.i/kg or 10% and 20% Granular respectively). It is a fairly toxic compound as shown by its Median Lethal Dose figures indicated below:

Ethoprop (technical grade).

Acute oral LD50	61.5 mg/kg (rats)
Acute Dermal LD50	25.9 mg/kg (rabbits)

Mocap 10% Granular -

Acute oral LD50	355 mg/kg (rats)
Acute dermal LD50	510 mg/kg (rabbits)

Acute inhalation LD50 = 20,000 mg/l (rats).

The Mobil Chemical Company described the characteristics of Mocap as "a phosphatic compound with a broad spectrum of activity as a nematicide - insecticide. It is a non-fumigant, non-systemic contact pesticide with good soil movement and residual properties. It can be

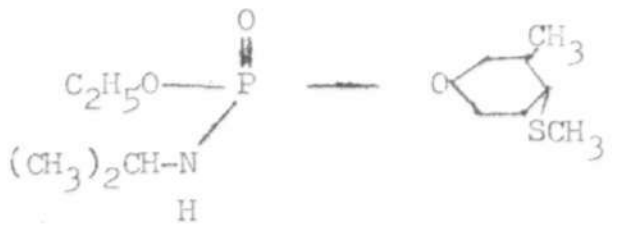
applied immediately before, or at the time of planting or be used for treatment of established plants" (Mobil Chemical Technical Bulletin "Mocap" No.10-1 Sept., 1973). Mocap provides effective nematode and soil insect control on a wide variety of field, vegetable and ornamental crops. In the U.S.A. Mocap was registered for use on such crops as sugarcane; soybean, corn, banana, plantain, groundnut, sweet potatoes, pineapple, limabeans, cabbage and cucumber with a tolerance level at harvest set at 0.02 ppm (Pesticide Manual p.249).

Argauer and Feldmesser (1978) investigated the uptake of Mocap by ten vegetables grown in treated soil for control of nematodes. Soils were treated with 3.4, 6.7, and 13.4 kg/ha active ingredient of Mocap 10% granules one week before planting. At harvest the chemical was found at levels above 0.01 ppm in onion bulb (0.12, 0.52, 1.34 ppm), carrot (0.14, 0.34, 0.81 ppm), radish (0.12, 0.33, 0.66 ppm), and eggplant (0.027, 0.044, 0.086 ppm). Mocap was not detected (i.e. lower than 0.01 ppm) in beet root, cabbage head, cantaloupe leaf, pea and tomato fruits. The results of this investigation proved the systemic action of Mocap and also showed that the chemical is quite safe for use on such common garden crops as tomato, pea

and cabbage. Several workers have demonstrated the effectiveness of Mocap used in controlling nematodes in tobacco (Brodie and Good 1973; Dickson 1974; Di Mure 1973; and McLeod and Mead 1977). Ingram Rodriquez, Kabana & King (1977) compared the efficacy of Mocap and Fensulfothion in control of M.arenaria in squash plants, and M.incognita and Tylenchorhynchus claytoni in cotton. They found that Mocap reduces galls more sharply than the other compound. McLeod (1977) reported that of the several granular nematicides tried against Meloidogyne spp. on tomatoes, the best results were obtained with mocap, aldicarb and oxamyl. Root galling was satisfactorily reduced for at least 5 months after treatment and, in one trial, yields were increased by 20 to 40 per cent. Vasheishwili (1976) reported a different experience when he found that Mocap at 75-100 kg/ha (actual formulation) had low efficacy for control of Meloidogyne spp. on tomato in the Georgian USSR.

2.5.4 Nemacur (Fenamiphos).

Fenamiphos is the common name for Nemacur which is an organophosphorus nematicide. Its active ingredient is O-ethyl-O (3-methyl-4-methyl-thiophenyl) - isopropyl amidophosphate, having as structural formula:



The compound was introduced in 1969 by Chemagro division of the Baychem Corporation as a nematicide under the trade mark "Nemacur".

Nemacur has a vapour pressure of 10^{-6} mm Hg at 30°C; solubility in water at room temperature is 700 mg/litre. The oral LD50 to male rotes is 15.3 mg/kg; and 500 mg/kg dermal LD50 for the same animal.

Nemacur is a systemic nematicide, active against ecto-parasitic and endoparasitic, free-living, cyst-forming and root-knot nematodes (see appendix iii). It is suggested for broadcast application at 5 to 20 kg a.i/ha, for band application at 7 to 40 g a.i/100m of row in 30 to 45 cm bands, for bare root dip at 100 to 400 mg a.i/litre for 5 to 10 minutes. (Pesticide Manual 5th Edn. (1977) p.262).

The active ingredient of Nemacur disperses in the soil via the water system and is then brought into contact with the nematodes in a systemic manner. Its

residual action in soil, at dosages of 5 to 10 kg of a ctive ingredient per hectare lasts for three to four months (Homeyer, 1971). Homeyer reported a successful use of Nemacur on a wide range of crops including tobacco, cotton, groundnut, carrot, tomato and cucumber. In field trials with Nemacur for the control of tobacco nematodes (Tylenchorhynchus claytoni, Pratylenchus crenatus and Meloidogyne spp.), the nematicide was applied in granular and liquid formulations, and incorporated into the soil. The results show that dosages of 4 to 8 kg of active ingredient per hectare, applied in bands, are adequate, even in severely infested soil, to obtain high levels of nematode control, good plant growth and full harvest yields. The application of 5 kg a.i/ha of Nemacur achieved 80 to 90% control of M.incognita and Rotylenchus reniformis attacking roots of cotton. Besides, the chemical also gave good control of sucking insects, particularly Thrips tabaci. All nematode species attacking groundnut were reportedly controlled with 5 kg a.i/ha of Nemacur. Carrots, which in Europe are infested chiefly by Paratylenchus sp. and Meloidogyne hapla had been effectively protected with Nemacur against these nematodes. In several trials, Nemacur, applied at

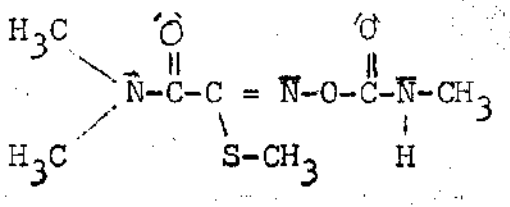
10 kg a.i/ha pre-sowing, both by broadcasting and by apraying, gave good levels of nematode control, which resulted in high yields and production of almost 100% marketable carrots. The carrots from the untreated control, on the other hand, were small and bodily malformed so that, on average, only 23% of them were saleable. Nemacur also proved a good chemical for use in tomato and cucumber. Trials results show that pre-planting overall applications of Nemacur at 10 kg a.i/ha provides good control of the nematodes. Band application at 2 kg a.i/ha gave only 35 to 50% control. Sadykhov and Treskova (1976) showed that Nemacur granules at 100, 150 and 200 g/m^2 had respective efficacy rates of 58.3, 70.8 and 85.8% against Meloidogyne arenaria on tomatoes in Azerbaidzhan, U.S.S.R.

The systemic nature of Nemacur calls for concern on how much residue is actually present in the final products of treated crops. Homeyer (1971) conducted trials to determine nemacur residues in tomatoes. Nemacur granules applied at the rate of 12.5 kg a.i/ha left a residue level of 0.1 ppm (probably in the fruit) after 137 days and 0.05 ppm after 163 days. Application of 5 kg a.i/ha left a residue level of less than 0.01 ppm . 124 days after

treatment. In two other trials, in which Nemacur granular was broadcast at dosages of 10 and 20 kg of active ingredient per hectare and incorporated, there were no detectable residues in the tomatoes after 79 days.

2.5.5 Vydate (Oxamyl).

Oxamyl is the common name of the chemical, Methyl N' N'-Dimethyl-N (methyl-carbamoyl)oxy)-1-Thiooxamimidate, whose structure is:



It was introduced by E.I. DuPont De Nemours & Company Inc. in 1969 and marketed under the trade mark "Vydate" oxamyl insecticide/nematicide.

Oxamyl is a white crystalline solid with a slight sulphurous odour; vapour pressure is 2.3×10^{-4}mm Hg at 25°C; solubility at 25°C in water is 280 g/kg and 1.44 kg/kg in methanol. It is stable in solid form and in most solutions, but decomposes to innocuous material in natural waters and in soil. Aeration, sunlight, alkalinity and higher temperatures increase the rate of decomposition.

Oxamyl is a potent anticholinesterase agent and a very toxic compound. In unformulated form, the oral LD50 for male rates is 5.4 mg/kg. The vydate L formulation has an acute oral LD50 of 37 mg/kg for male rats. The skin absorption LD50 for this formulation is 2960 mg/kg for male rabbits. There is a good measure of safety in the 10% granular formulation which has low dermal LD50 of 5000 mg/kg for rabbits.

According to DuFont information Bulletin, Oxamyl controls nematodes by contact and systemic action. Rates of 5 ppm or above in the soil kill nematodes by direct contact in a short time, and lower concentrations kill nematodes if they are exposed to the chemical in soil for an extended time. Bunt (1975) however reported something different. He found that when nematodes treated in as high as 4,000 ppm a.i oxamyl for 3 weeks were transferred to water, some were able to recover completely and others partially malformed. He also found that nematode poisoning with oxamyl was reversible for treatment concentration up to 10,000 ppm a.i within an exposure period of 24 hours.

According to DuPond information Bulletin, oxamyl systemically provides a degree of protection from nematodes

when applied as a foliar spray or through the roots of the plant. In the soil, low concentrations of oxamyl inactivate parasitic nematodes and inhibit feeding during exposure. Oxamyl has been shown to provide good control of a wide range of parasitic nematodes. The compound is also a systemic, moderately residual insecticide when applied as a foliar spray and can control such pests as thrips, aphids, whiteflies, leafhoppers, mealybugs and mites.

Oxamyl has been evaluated for the control of Ditylenchus destructor in potato, sugarbeet and onion. Significant increase in yields of these crops and reduction in the rate of nematode population growth were recorded (Allison, Sinclair & Smith 1973). McLeod and Mead (1977) tested 7 non-fumigant nematicides against M.javanica and M.incognita on infected tobacco seedlings. Aldicarb, Nemacur, Mocap and Oxamyl gave similar levels of control. But oxamyl persisted better on alluvial loam soil. Foliar applications of oxamyl at a rate of 1.8 kg per 100 gallons of water controlled Meloidogyne incognita on several host plants (tobacco, pumpkins, sweetpotato, polebeans and tomato) for periods ranging from 21 to 28 days. In one trial, rates as low as 500 g per 100 gallons gave good

control of M.incognita and lesion nematode, Pratylenchus scribneri Steiner. Foliar sprays are prophylactic in action; however, if infection has occured before sprays are applied, apparently the rate of nematode development is reduced or the reproductive potential diminished (Radewald, Shibuya, Nelson, and Biven 1970). Abawi and Mai (1972) tested the mode of action of oxamyl in controlling Pratylenchus penetrans in seedling roots of peach, pear and apple. Two foliar applications of oxamyl at 2-week intervals drastically reduced numbers of all stages of the nematode in roots of seedlings treated before or after inoculation with the nematode. In comparison with treated controls, two foliar sprays at rates of 9.07, 6.80, 4.54, 2.27 g a.i per gallon water reduced populations of lesion nematodes in roots of peach seedlings by 95.2, 94.0, 89.7 and 47.8% respectively. Larger numbers of nematodes were found around roots of treated than untreated seedlings during the first 3-4 weeks after inoculation, indicating that oxamyl in roots prevented invasion of P.penetrans.

2.6.0 Method of Estimating the Population of Meloidogyne in the Soil.

Demeure and Netscher (1973) have enumerated a number

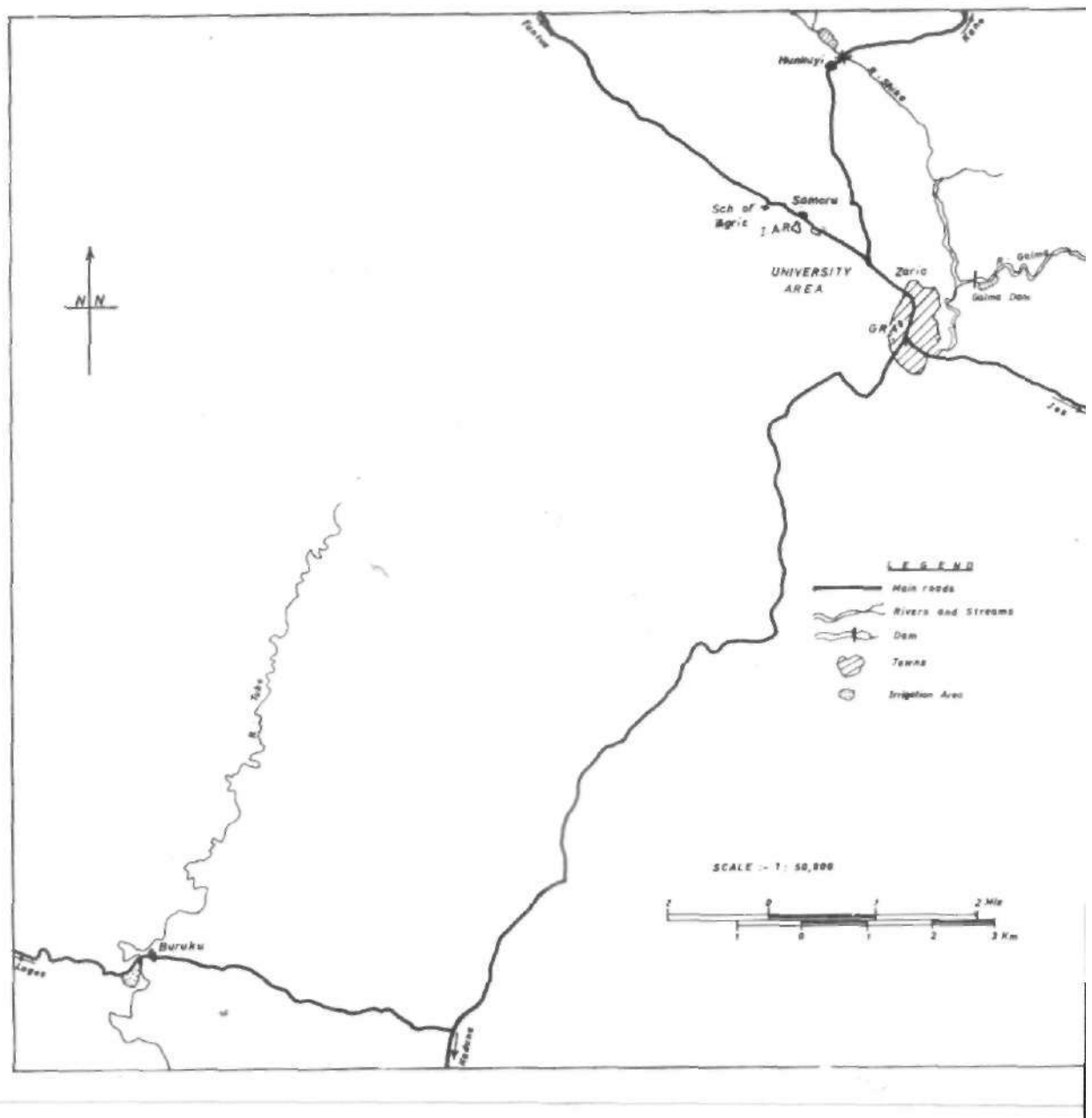
of reasons why it is essential to be able to evaluate accurately the level of soil infestation by Meloidogyne: An accurate evaluation method makes it possible to determine the threshold of critical infestation of a soil, that is the rate of population above which damage is expected for a number of crops; and also to determine the immediate effect the different cultivation techniques such as rotation, soil preparation and dessication have on the population of the Meloidogyne. The two researchers recognised however that no entirely satisfying method of knowing the level of infestation of a soil had yet emerged. This is due in part to the fact that the Meloidogyne are in different forms. They can be: either in the second stage of active larvae; or in form of isolated eggs or eggs agglomerated in mass of eggs, some of these may be available in a sedentary state. The methods generally used enables only the extraction of active 2nd stage larvae leaving off the immobile larvae, isolated eggs or egg masses. However, Demeure and Netscher (1973) reported that the above ommissions can be corrected if Seinhorst's mistifying extractor is used. But this also has its limitations in that it works only with soils which percolate easily.

2.7.0 Rating Scheme for Field Evaluation of Root-knot Nematode Infestation.

A rating scheme based on the severity of root galling in the tomato plants was used as an index of the level of root-knot nematode infestations in the fields. Feldmesser and Feder (1955) arrived at an index of infestation 4 weeks after planting according to a five-step scheme, in which "0" mean "no infestation" and "4" means heavy galling. Zeck (1971) observed that the scheme is hardly sufficient to quantitatively determine the degree of infestation of field crops like tomatoes, tobacco, cucumber, okra etc., particularly when this determination takes place at harvest. Several cycles of reproduction, re-infestation and coalescence of galls would have taken place. The number of galls by itself may not be sufficient then, but the size of the galls has to be considered. Dropkin (1954) found that with a given plant the size of the gall is dependent on the number of nematodes attacking the root at a spot. Consequently, the size of the gall at a given time correlates to the time of infestation. He also showed that the size of the gall at a given time correlates to the time of infestation. The earlier the infestation is initiated, the larger the resulting gall.

Zeck (1971) took these points into consideration when he introduced the eleven-step rating scheme in which "0" represents no infestation and "10" means total destruction of the plant. However, Taylor and Sasser (1978) suggest a six-step scheme of "0 to 5" infestation classes which is stated in page 50. This scheme, they recommend for the diagnosis of early infestation on seedlings 4-5 weeks old. At this stage the root-knot symptoms have developed but there has been no time yet for the nematode population to increase by reproduction.

Plate 1



The Map showing the experimental sites.

CHAPTER 3

General Materials and Methods

3.1 Preparation of Plots.

Fields known to be highly infested with root-knot nematodes were selected from areas within and outside Samaru (Plate 1). The selected sites were ploughed and prepared to a fine tilth. Blocks and treatments were then pegged out according to the various experimental field plans. Samples of soil were taken to determine the soil texture and pH using the "Hydrometer method" and an electrical pH-meter respectively. From every plot of the trials, about 300 grams of soil sample - a composite of 12 subsamples - were taken in a random pattern that covered the whole plot. These samples were taken at a depth of 0-25 cm with a soil auger. Nitrochalk compound (21%N, 28%CaO) fertilizer was applied to the plots as base dressing at a rate of 500 kg/ha.

3.2 Treatments.

The nematicides tested were Basamid, DD, Nemacur, Mocap and Vydate. Each chemical was applied at four levels as follows: Two times the amount recommended by

the manufacturer; the exact amount recommended; one-half; (and in some cases, one-quarter and one-eighth of the recommended dose were included in the trial). There was always a control where no nematicide at all was used. Of each chemical the calculated amount needed for each plot was weighed or measured out prior to application. DD was applied with a hand injector, while the other chemicals - all in granules - were broadcast and incorporated into the soils with a hand hoe to a depth of about 0-18 cm, depending on the chemical. After the waiting period recommended by the manufacturer of the nematicide had lapsed so that the danger of phytotoxicity was removed, the plots were planted with tomato seeds of variety "Nadipoli". Seeds were sown thinly along two rows on each bed at a depth of 15 mm. Beds were watered with cans (fitted with fine hoses) every morning during the dry season or drought period.

Where transplanting of seedlings was necessary, as in the case of Mocap trials, seedlings were transplanted when the they had developed 3 to 4 leaves or attained 12 to 15 cm in height. The seedbeds were soaked thoroughly the day previous to planting, and lifting was made with a hand fork. A ball of earth was retained at the roots of each

plant while in transit. Transplanting was done during early morning or late afternoon.

Routine weeding and spraying against fungal diseases or insect attack were carried out as it became necessary. At 3 weeks after transplanting side dressing of Ammonium sulphate was applied at the rate of 125 kg/ha. Except where furrow irrigation was used a thick mulch of straw was applied on each plot to conserve moisture.

3.3 Field Evaluation of Root-knot Nematode Infestation.

Root galling was assessed at seedling and mature plant stage according to the scale suggested by Taylor and Sasser (1978). This is a 0-5 scale representing the following infestation classes:-

0 = no galls
1 = 1 - 10 galls
2 = 11 - 20 galls
3 = 21 - 50 galls
4 = 51 - 100 galls
5 = 101 or more galls.

The data was then transferred into percentage effectiveness of the treated compared with the untreated plants as recommended by Abbot (1925) i.e. Effectiveness (%)

$$= \frac{\text{Degree of infestation in control} - \text{Degree of infestation in treatment}}{\text{Degree of infestation in control.}} \times 100$$

3.4 Extraction of Second Stage Meloidogyne Larvae from the Soil.

The soil samples taken from field plots were examined for the presence of active second stage Meloidogyne larvae. The extraction of the nematodes from the soil samples was by using Oostenbrink elutriator Model III. After the extraction the recovered nematodes were examined under a binocular microscope (x 40 magnification), and the number of second stage Meloidogyne larvae per 100 cc of soil was determined.

Perineal patterns of some ten females of the Meloidogyne spp. occuring at each site were cut and prepared into slides. The species were later identified. Other species of nematodes occuring in some of the sites were also recorded.

3.5 Harvesting.

Fruits were harvested regularly and weighed. An average of four or five harvests was obtained from each experiment. Stand-counts, total fruit weight per plot and per

plant, and the average of four or five replicates (as the case may be) of each treatment were calculated and tabulated. The data so obtained were later subjected to an analysis of variance.

3.6 Statistical Analysis and Interpretation of Data.

The designs (CRBD and Latin Square) in the trials permitted statistical analysis of data by the technique of analysis of variance associated with each design. Regression analyses were also done to detect the type of correlation that existed between some variable factors. Most of the data analysis and transformation was done by computer. In order to ascertain whether the observed treatment effects were significant and discernible from chance effects they were tested by the "F" test of significance . In cases where the test revealed the significance of treatment effects, LSD (least significant difference) and Duncan Multiple Range test at 5% level of probability were computed to elucidate the nature and magnitude of treatment effects.

The coefficient of variation (cv) (which is the ratio of the standard deviation to the population mean expressed as a percentage) was applied to determine variability of the experimental results. Where the cv was high (i.e.

exceeding 25%) the data were subjected to some form of transformation before the performance of analysis of variance.

CHAPTER 4

Comparison and Appraisal of the Five Nematicides

4.1 Materials and Methods.

Since the efficacy of the nematicides to control root-knot nematodes was the main issue of our work, it was appropriate to select sites for trial which have appreciable levels of Meloidogyne infestation. Taylor and Sasser (1978) stated that land for nematicide experiments should have a moderate infestation of Meloidogyne species, the level of infestation being determined by the use of "indicator plants". With these points in mind, the sites selected for the trials were Hunkuyi irrigation site and the Horticultural garden of the College of Agriculture Samaru (see map 1). These places had previously been cropped with tomatoes and samples we took had shown heavy root galling due to root-knot nematode infestation.

At Hunkuyi the experiment was carried out on $120m^2$ land. The nematicides used were Basamid, DD, Mocap and Nemacur - each applied at three levels (viz: half-dose, standard-dose and double-dose of the recommended dosage by the proprietors). Hence there were 13 treatments,

replicated four times, and arranged in a complete randomized block design. Each plot measured $4.5m^2$. The soil texture was sandy clay loam with and average pH of 5.6.

The experiment was started by the middle of May, 1978. The population densities of the second stage of active larvae were assessed 3 weeks after the land preparation and just before the application of the treatments to the plots. The nematicides were applied in a manner described in section 3.3 above. Basamid at phytotoxic levels was still present in the soil four weeks after application inspite of soil-turning twice a week. This must have been due to the wetness of the soil brought about by the rains. After four weeks it became necessary to turn over the soil daily for a whole week in order to facilitate the vapourisation of Basamid residues before the planting of tomato seeds.

Seeds of "Napoli" - a susceptible tomato variety were sown five weeks after the application of the chemicals. Each plot or bed was mulched, and watered when necessary. Germination occurred 8-10 days after planting. Four weeks later samples of 50 seedling plants per plot were taken and examined for the presence of nematode galls on the roots.

At Samaru, the trial was carried out on 120m^2 land. The same chemicals listed above were used except Nemacur which was replaced with Vydate. There were 18 treatments replicated four times and arranged in a complete randomized block design (see plate 2). Each plot was 2m^2 separated at one metre spacing. The soil texture was sandy loam and pH 6.8.

The experiment was started in December, 1978, i.e. during the dry season, so regular watering of the plots was necessary throughout the period of the experiment. After each plot had been sampled for the count of the second-stage active larvae of Meloidogyne the chemicals were applied. Eleven days after the applications seeds of Napoli were sown on the plots treated with Mocap, Vydate and the control. Nine days later, those treated with Basamid and DD were also planted. Each plot was planted with 150 seeds, and the germination count was taken two weeks after the emergence of the seedlings.

When the seedlings were 5 weeks old, 50 plants were sampled from each plot and scored for the incidence of root-knot, using an index of 0 to 5. The plant heights were measured to obtain the mean height of plants per treatment. The plants were thinned at 5 weeks to 10

LAYOUT OF TOMATO SEEDBED TRIAL OF FOUR NEMATICIDES (at Somaru)

13	18	8	4	15	8	16	10	
9	2	7	18	1	13	14	13	
5	4	15	14	2	11	8	17	
15	7	10	2	9	3	11	4	
6	14	13	3	10	5	6	7	
16	3	9	1	7	12	9	5	
8	1	11	6	16	14	12	18	
11	10	16	5	6	18	1	15	
12	17	12	17	17	4	3	2	

Design 4 x 4 RCBD
Plot size (2x1)m and 2m spacing

TREATMENT - CHEMICALS-4

No	Treatment			
1	Basamid	80Kg/ha (21mts)	recommended dose	"
2	"	40D " "	(normal)	"
3	"	20D " "	(½)	"
4	"	10D " "	(¼)	"
5	DD	60D	(½ (21mts)	"
6	"	30D	" (normal)	"
7	"	15D "	(⅛)	"
8	"	7S "	(¼)	"
9	Nacap	20D	Kg/ha (2 tmts)	"
10	"	10D "	(normal)	"
11	"	5D "	(½)	"
12	"	2S "	(¼)	"
13	Hydate	11D "	(2 tmts)	"
14	"	5S	(normal)	"
15	"	27S "	(½)	"
16	"	13 7S	(¼)	"
17	Control			
18	"			

PLATE 2

plants per plot in an even spacing of 20 cm between the plants. Where necessary some were transplanted within the same plot. The plants were sidedressed with Calcium ammomium nitrate fertilizer at the rate of 250 kg/ha.

Yields data were taken for the weight of mature fruit harvested. After the last picking the plants were dug out and the roots scored for the incidence of root-knot, using again, an index of 0 to 5.

4.2.0 Results and Discussions.

4.2.1 Counting the 2nd stage of Active Larvae (L2) to Estimate Meloidogyne Population.

The number of active L2 found have not generally reflected the level of soil infestation by the root-knot nematodes. Counts of L2 made from three sites: Hunkuyi, Samaru and Government Residential Area (GRA) are shown in Appendix 1, 2 and 3 respectively. All the sites had one thing in common: they were previously planted with tomato crop, samples of which showed heavy root galling on examination. The very low count recorded in Appendix 1 can be attributed to the long exposure (3 weeks) of the tractor-prepared soil to dryness before sampling. Taylor

and Sasser (1978) have reported that larvae and eggs die in dry soil but can survive as long as there is enough moisture to maintain the soil air at nearly 100% humidity. Although it was not measured, the soil humidity was likely to be less than 100% after the three weeks of exposure to solar radiation and without rain. The other sites, Samaru and G.R.A. where the L2 figures were much higher, land preparation was done by hand using hand hoe, and sampling followed immediately after the plot lay-out. The main reasons why the number of the active L2 extracted does not generally reflect the level of soil infestation is that the active L2 is only a fraction of the root-knot nematofauna in the soil. The other forms of Meloidogyne, the inactive L2, eggs and agglomerated eggs present are not extractable by the method used (Demeure and Netscher, 1973).

4.2.2 Effects of the Nematicides on Root-knot Control of Tomato Seedlings.

In the trial at Humkuyi the level of the root-knot nematode infestation turned out to be generally low. This is indicated by the amount of the root-knots found present on the control plants (Table 4-1), where less than two knots per plant were seen. Comparing the performance of the chemicals under this condition, Nemacur appeared to

be the most effective of the nematicides used. Its effectiveness ranges from 99.3% at half-dose to 100% at the double dose. Basamid, DD and Mocap also have prevented any gall formation at double the recommended dose. All the treatments have shown a significant effect on reducing knot formation on the seedling roots (Fig. 4-1). As the Meloidogyne population has been shown to be generally low, no conclusion seems warranted on the relative efficacy of the nematicides.

At Samaru where the nematode population was higher (Table 4-2), all the chemicals viz: Basamid, DD, Mocap and Vydate significantly reduced galling on the roots of the tomato seedlings. Vydate took the lead in the effectiveness with a range of 97 to 100 per cent at 5 weeks from a quarter to double dose application respectively (Fig. 4-2, Table 4-2). The lowest level of application (which was one-quarter of the recommended doses) also gave significant reduction in root galling. In the case of Basamid and DD however, the galling index of plants treated with one-quarter the recommended dose is significantly higher than those receiving the normal and double dose treatments. Still these levels of treatment produced over 70% control of galling on the roots of tomato seedlings.

Table 4-1

Effect of soil fumigants on root-knot control of tomato plants at 5 weeks (Hunkuyi site)

Soil treatment	Application rate/ha	Mean root-knot count/plant	Effectiveness in %
Basamid	200 kg/ha	0.23	83.7
	400 "	0.07	95.0
	800 "	0.00	100.0
DD	150 lit/ha	0.16	88.7
	300 "	0.03	97.9
	600 "	0.00	100.0
Mocap	50 kg/ha	0.37	73.8
	100 "	0.18	87.2
	200 "	0.00	100.0
Nemacur	50 kg/ha	0.01	99.3
	100 "	0.05	99.6
	200 "	0.00	100.0
Control	0 kg/ha	1.41	-

Table 4-2

Effect of soil fumigants on root-knot control of tomato plants at 5 weeks (Samaru)

Soil treatment	Application rate/ha	Mean root-knot index 0 to 5	Effectiveness %	Mean plant height at 5 weeks
Basamid	100 kg/ha	0.30 c	75.7	18.9 d e
	200 "	0.17 a b c	86.0	16.6 b c d e
	400 "	0.04 a b	97.0	17.7 c d e
	800 "	0.15 a	98.8	16.3 b c d e
DD	75 li/ha	0.35 c	71.3	17.2 c d e
	150 "	0.28 b c	77.3	18.8 d e
	300 "	0.07 a b	94.6	19.1 e
	600 "	0.02 a	98.8	17.8 d e
Mocap	25 kg/ha	0.12 a b c	90.1	13.2 a
	50 "	0.04 a b	96.5	11.2 a
	100 "	0.03 a b	97.5	9.1 a
	200 "	0.00 a	100	7.8 a
Vydate	13.75 "	0.04 a b	97.1	14.4 a b c d
	27.5 "	0.03 a b	97.5	14.6 a b c d e
	55 "	0.01 a	99.6	13.0 a b
	110 "	0.00 a	100	11.5 a
Control	0	1.21 d	0	12.4 a

Mean with the same letter are not significantly different at P = 0.05 with Duncan Multiple Range Test.

FIG. 4-1. GALL DEVELOPMENT ON ROOTS OF TOMATO SEEDLINGS GROWING IN SOILS TREATED WITH CHEMICALS

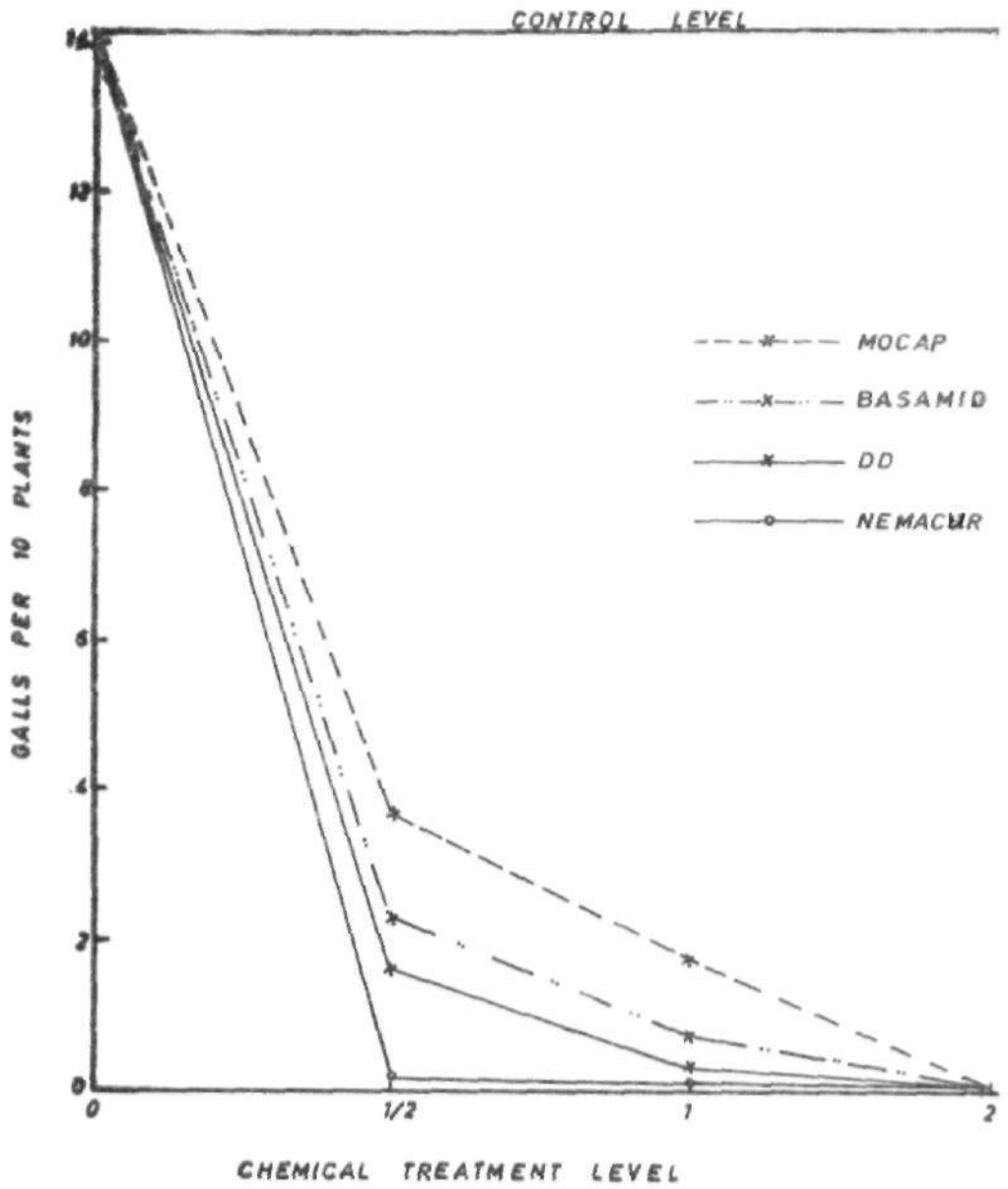


FIG. 4-2: EFFECT OF NEMATICIDES ON ROOT-KNOT INDEX OF TOMATO PLANTS AT 5 WEEKS AND 12 WEEKS

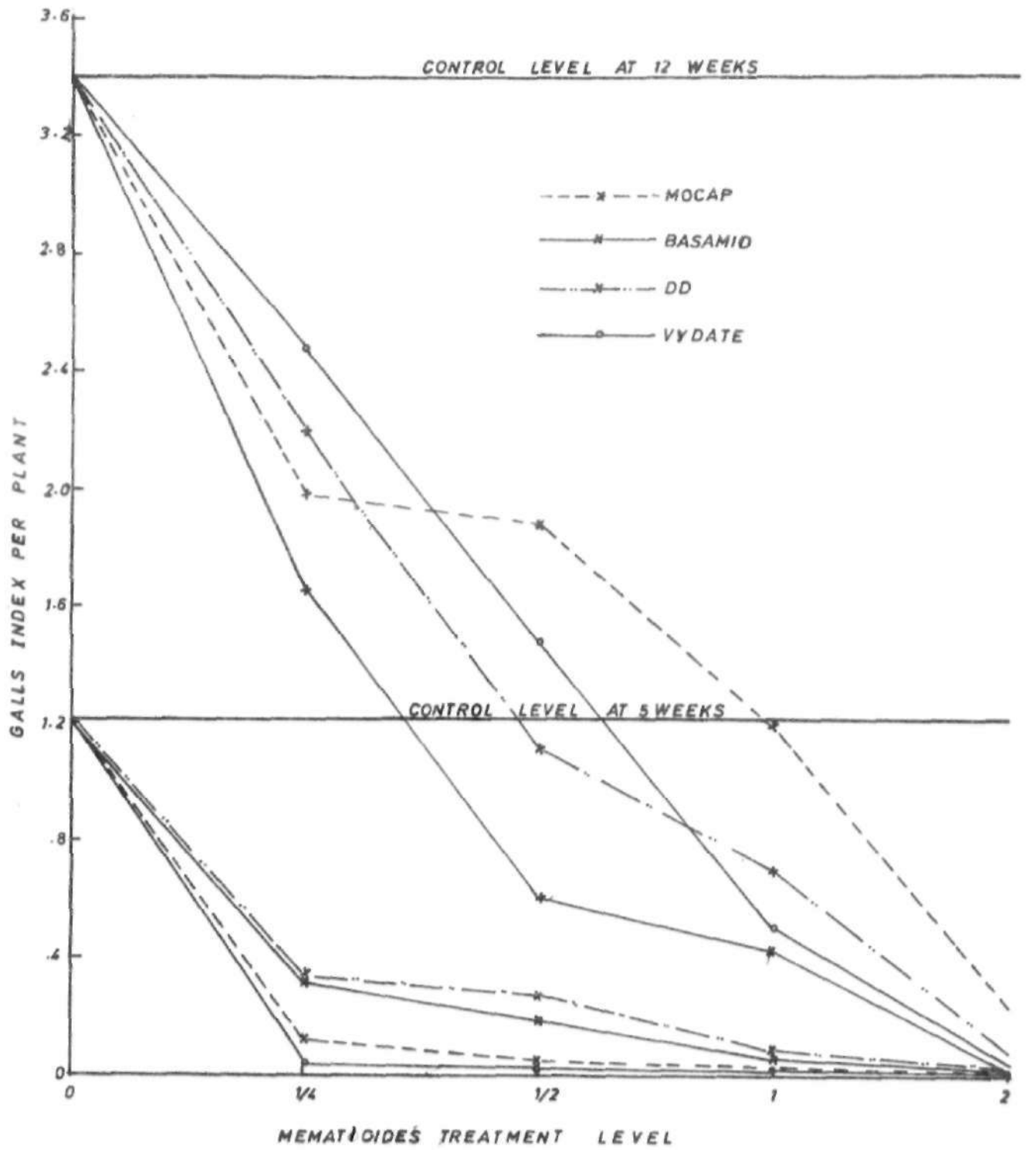


Plate 3 shows the extent of galling on roots in control plots.

The effects of the nematicides on galling of tomato roots at 12 weeks are shown in Fig. 4-2 and Table 4-3. Once again the effect of all the treatments in reducing root galling is very noticeable. Except at the lowest level of DD, Mocap and Vydate, all other levels controlled root galling significantly. Of the four chemicals, the effect of Basamid appeared to last longest: in the one-quarter dose treatment, at 12 weeks, galling was still significantly lower than in the control. The effectiveness of Vydate, Mocap and DD treatments at lower rates over the same period was much less.

4.2.3 Effect of the Nematicides on Germination.

The germination count following treatment with nematicides is shown in Table 4-4. The germination counts taken two weeks after sowing were fairly high and uniform for all treatments except for those of the Mocap. Mocap at higher levels tended to inhibit germination of seeds planted 7 days after the application. Mean germination percentages of only 16% and 46% were recorded for plots treated with the double and the standard recommended rates respectively. Germination in the half-dose and

Plate 3



Selected tomato seedlings (5 weeks old) from untreated plots (control) showing heavy root galling.

Table 4-3

Effect of Selected Nematicides on Root-knot Control of tomato plant at 12 Weeks

Soil treatment	Application rate/ha (actual formul.)	Mean root-knot index (0 to 5)	Effectiveness in %	Yield inc./ plant in %	Yield plant (g)
Basamid	100 kg/ha	1.63 b c	52.3	8.6	508.0
	200 "	.62 a b	81.9	40	655.3
	400 "	.43 a b	87.4	11.6	522.1
	800 "	.11 a	96.8	.28	454.9
DD	75 lit/ha	2.19 d	36	.74	471.5
	150 "	1.12 b c	67.3	6.3	497.5
	300 "	.72 a b c	78.9	11.8	522.6
	600 "	.08 a	97.7	19.1	557.6
Mocap	25 kg/ha	1.91 c d	44.2	28.9	603.1
	50 "	1.93 c	43.6	17.7	530.6
	100 "	1.21 b	64.6	9.7	513.5
	200 "	.24 a	93.0	7.1	501.0
Vydate	13.75 kg/ha	2.46 d	28.1	68.4	787.9
	27.5 "	1.48 b c	56.7	26.4	591.6
	55 "	.50 a b	85.4	86.7	873.6
	100 "	.03 a	99.1	76.0	823.7
Control	0 kg/ha	3.42 d	-	0	468

Mean with the same letter are not significantly different at P = 0.05 with Ducan Multiple Range Test.

Table 4-4

Effect of Nematicides on Germination

Count of tomato seeds (at 2 weeks)

Soil treatment	Application rate	Mean germination count	% Germination
Basamid	100 kg/ha	120	80
	200 "	131	87
	400 "	117	78
	800 "	130	86
DD	75 lit/ha	126	84
	150 "	122	81
	300 "	126	84
	600 "	118	78
Nocap	25 kg/ha	129	86
	50 "	118	78
	100 "	69	46
	200 "	24	16
Vydate	13.75 "	146	97
	27.5 "	147	98
	55 "	117	78
	100 "	121	81
Control	0 "	133	88

the quarter-dose plots was fairly high and comparable with the other chemicals. In the case of plots treated with double dose, many of the plants were malformed (Plate 4). The plants grew with "C" - shape stem; the rooting system was poorly developed and lacked a taproot.

4.2.4 Effect of the Nematicides on Plant Heights.

According to the I.A.R.* recommendations, tomato seedlings are ready for transplanting when they have developed 3 to 4 true leaves or attained 12 to 15 cm in height[1]. Height is a useful parameter to consider when treating tomato seedlings with nematicides. The effect of the nematicides on the linear growth of the seedling by 5 weeks is shown in Fig. 4-3. From the figures, it appears that Mocap caused an almost linear decline in plant height from the low level to high levels. Thus, whereas at 200 kg of Mocap per hectare the plants attained a height of about 8 cm, at 25 kg/ha level, the plants progressively reached an average of 13 cm height -- just 1 cm longer

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* = Institute for Agricultural Research, Ahmadu Bello University, Zaria.

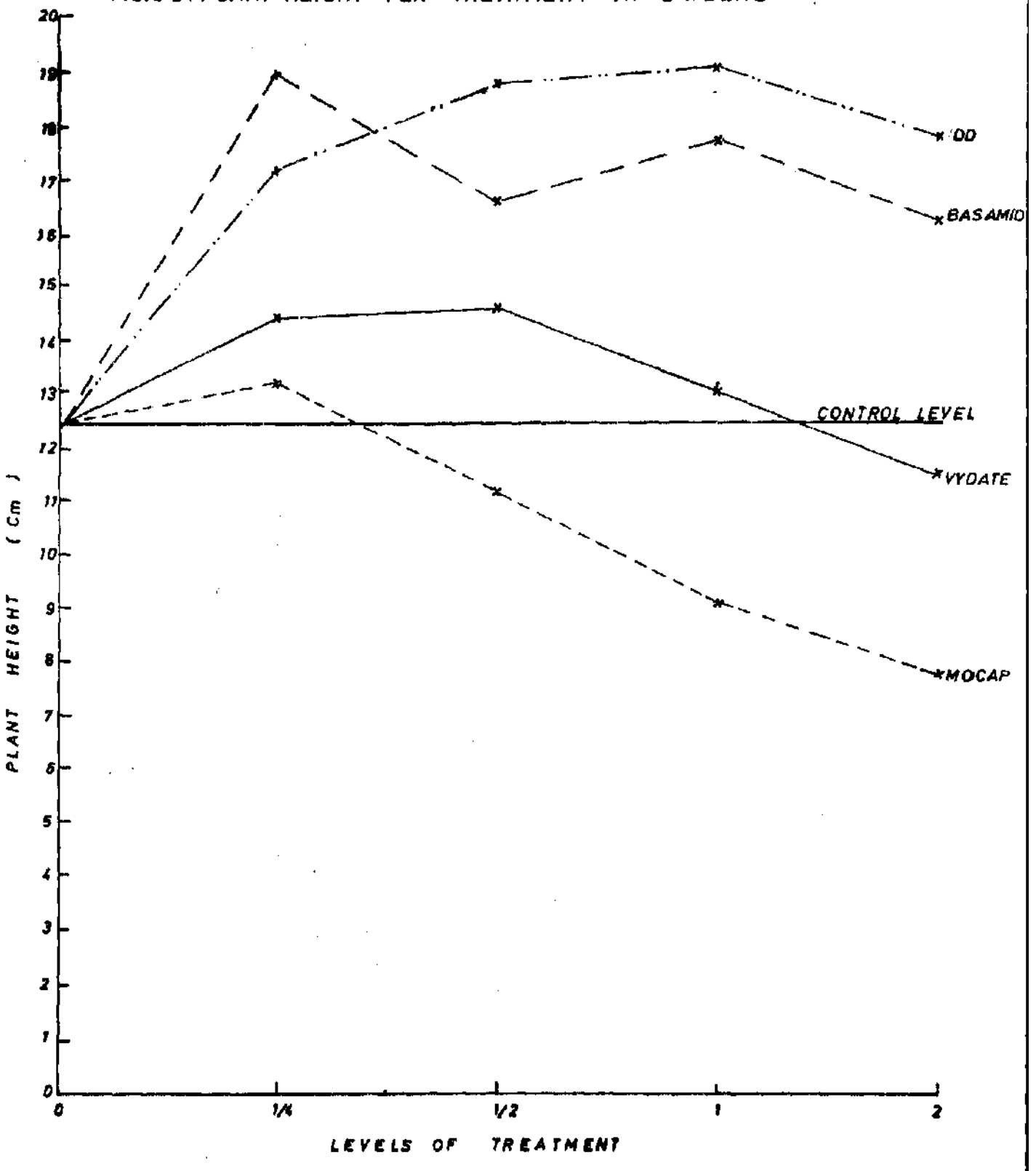
1 = Extension Guide No.1: Guide to the Production of tomato.

Plate 4



Tomato seedlings growing in Mocap-treated plot (double dose); plant malformation and poor rooting system indicate phytotoxicity of the chemical.

FIG. 4-3 : PLANT HEIGHT PER TREATMENT AT 5 WEEKS



the time of application (Appendix 18). The seedlings attained a maximum average height of 14.6 cm at 27.5 kg/ha (half dose) level of treatment and 11.5 cm at 110 kg/ha (double dose) level of treatment. Though there is a general increase in the height of all plants treated with 13.75 kg/ha (one-quarter) dose, half dose, and single dose of Vydate over those from the control plots, the increase is not significant. Basamid, and DD treated plots have produced plants significantly taller than those of the control plots. Basamid in the soil, kill insects, weeds, bacteria, fungi as well as nematodes. DD is known to kill these organisms as well, especially when applied at high concentrations (Personal communication from Ir. Bos, Zaria). The broad spectrum of activities of the two chemicals, are likely to be responsible for the higher growth rate of the seedlings.

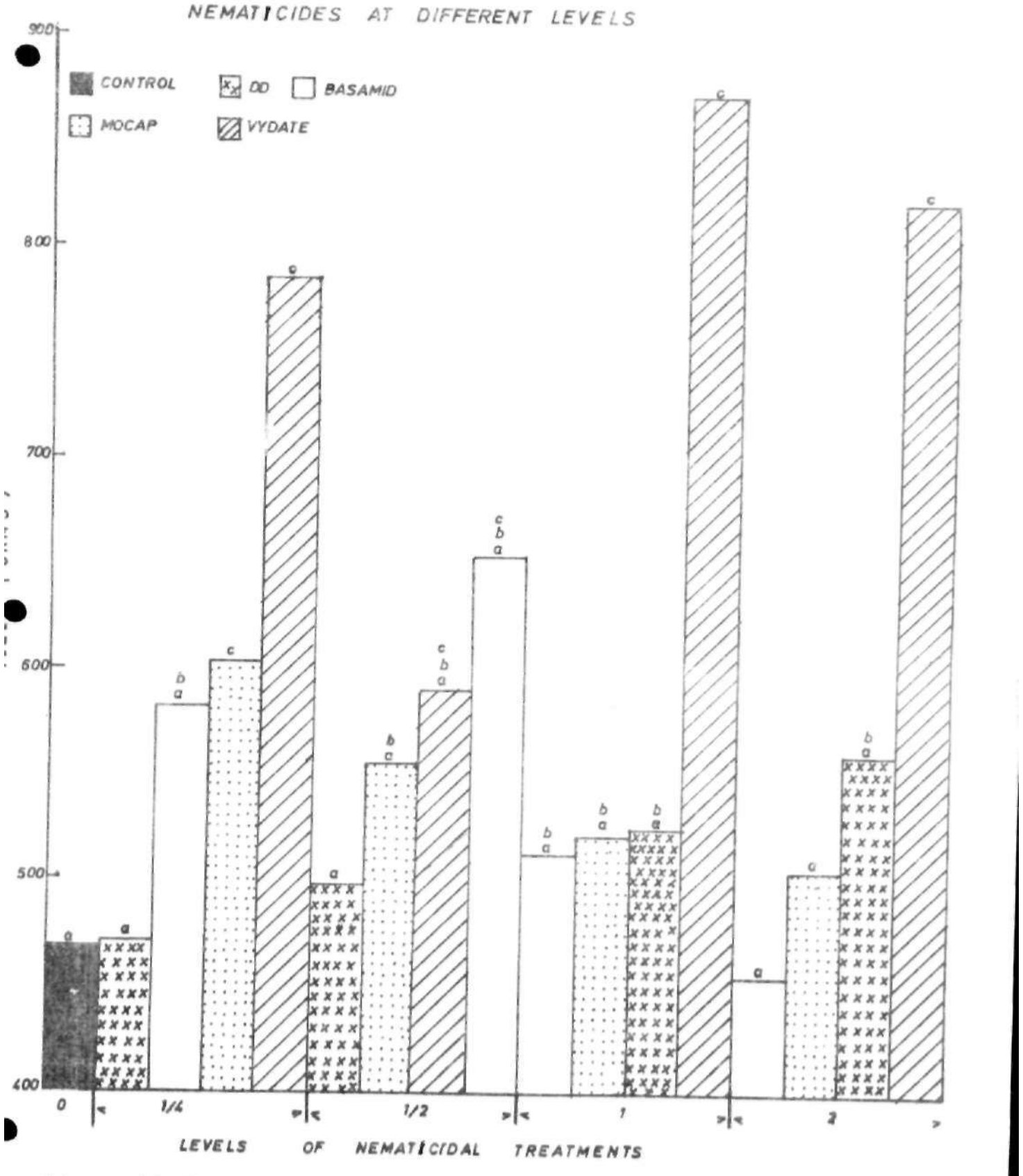
There was no correlation between the root-knot index and the plant heights because of the toxic effect of some of the treatments at high dosages. But it can still be generally observed that the gall-free plants grew taller than the galled seedlings (Table 4-2 and Plate 5). This observation agrees with Oteifa and Elgindi's (1962) finding that plant growth is retarded when the translocation

Plate 5.



Comparing the heights of root-galled and gall-free tomato seedlings at 5 weeks old.

FIG. 4.4: MEAN YIELD PER PLANT OF TOMATO TREATED WITH 4 NEMATICIDES AT DIFFERENT LEVELS



Columns with the same letters are not significantly different at P=0.05 with duncan multiple range test

formed best of them all. The increases in the yield are generally high; the lowest dose of 13.75 kg/ha still produced a yield increase of 68% over the control. Besides controlling root-knot nematodes, Vydate appears to have improved both the vegetative growth and the fruiting quality of tomato planting though it has no fungicidal activities.

In order to ascertain the relative sizes of the fruits of various treatments, the first twenty largest fruits of three successive harvests were selected and weighed. Selection was based on visual impression. The mean weight per treatment was found and from that, the average large fruit weight producable by the plant was calculated (Table 4-5). Large fruits of Napoli can be obtained from all levels of Basamid and DD treatments. The higher levels of Vydate treatments produce large fruits, but the lower levels produced relatively smaller fruit sizes though not significantly. Mocap produced smaller fruits than the other chemicals.

Table 4-5

Effect of Nematicides Treatment on Fruit Size.

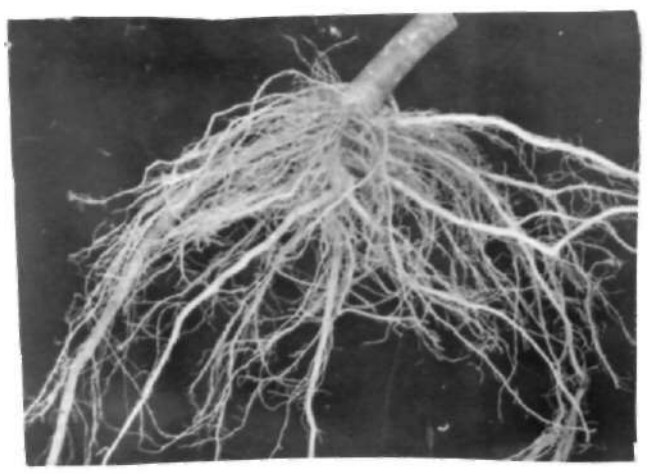
Treatment	Application Rate	Mean Wt (g) of 20 largest fruits	Average fruit Wt.(g)
Basamid	100 kg/ha	639	31.9
	200 "	647	32.3
	400 "	651	32.5
	800 "	686	34.3
DD	75 lit/ha	619	30.9
	150 "	669	33.5
	300 "	587	29.4
	600 "	709	35.5
Nocap	25 kg/ha	491	24.6
	50 "	487	24.4
	100 "	566	28.3
	200 "	607	30.3
Vydate	13.75 "	583	28.4
	27.5 "	592	29.5
	55 "	665	33.3
	110 "	704	35.2
Control	-	542	27.1

4.26 Effect of Nematicides on Root Development of Tomato Plants.

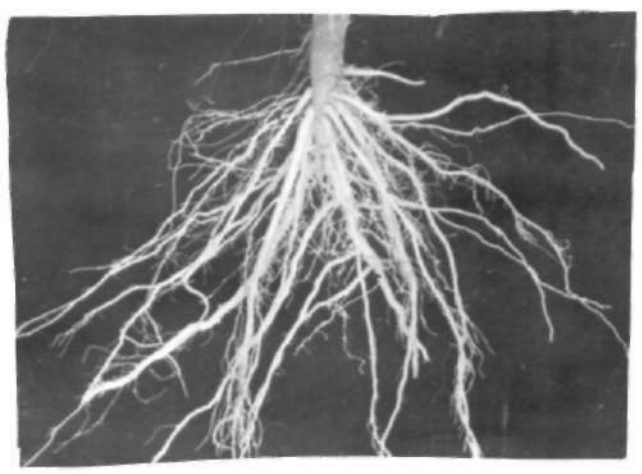
The roots of plants treated with the normal recommended dose of each nematicide were carefully dug out after the last fruit harvest. They were washed and examined, photographs of representative roots of each treatment were taken (Plate 6). All the chemicals at the recommended level of application gave good control of root knotting - (compare fig. A. B. C. and D). Roots of Vydate, Basamid and DD - treated plants had more feeder roots than those of the Mocap and the control. Vydate in particular, has encouraged a lot of feeder-root formation, this may as well explain why the yields from the Vydate-treated plants are higher than any other.

PLATE 6

A



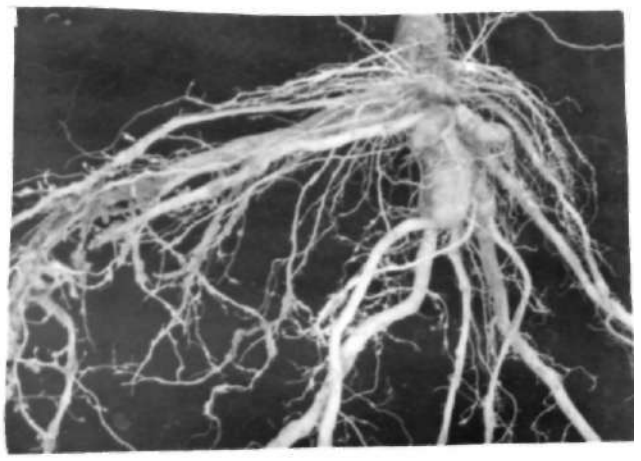
B



C



D



Tomato root-system under various treatments of nematicides. Treatments are (A) 400 kg/ha Basamid, (B) 100 kg/ha mocap, (C) 55 kg/ha Vydate and (D) No chemical applied (control)

CHAPTER 5

The Appraisal of Mocap on Root-knot Nematode Control on Tomato

5.1 Materials and Methods.

The general materials and methods used in the application of Mocap nematicide have already been discussed in (3.2). The chemical was tried in three localities where different levels of soil infestation by root-knot nematodes were found. At Hunkuyi, where the crop was raised under rain-fed conditions, the average population was 310 active larvae per 100 cc of soil. The soil at Buruku had low count of 2nd stage active larvae (or active L2) at the commencement of the experiment (in December, 1978). At the G.R.A. the level of infestation averaged 1380 per 100 cc of soil sample. The experiment there started in February, 1979.

5.1.1 Hunkuyi Trial

At Hunkuyi four levels of Mocap were tried on Napoli and Roma VFN in a 2 x 4 Factorial experiment with 4 blocks in a Randomised Complete Block Design (Fig. 5-1). The levels (actual formulation) were 100 kg/ha, 25 kg/ha,

12.5 kg/ha and 0 kg/ha, the latter being control. They were applied to plots of $1\frac{1}{2} \times 15m^2$ on the day of transplanting (Fig. 5.1 and Plate 7).

The inclusion of a resistant variety, Roma VFN, was to test any phytotoxic effects of the chemical on tomatoes, and to enable us to follow up with a tomato yield trial during the next season in this field whereas various plots would have obtained different levels of root-knot nematodes. Unfortunately, the land was no longer available.

Transplanting of tomato seedlings was done five weeks after sowing. Before the transplanting, ammomium sulphate and superphosphate, were applied as a base dressing at the rate of 500 kg/ha each. Side dressing of 250 kg/ha of ammomium sulphate was applied four weeks later. Foliar application of fungicides commenced three weeks after transplanting and continued for five weeks, using Difolatan-5 in U.L.V. formulation. The spraying frequency of once a week was doubled during the third week when fungal infection (Septoria, Alternaria and Cladosporium leaf spots) on the leaves became very severe. A thick straw mulch was applied to each bed in order to reduce soil splashing and disease incidence on the fruits. Harvesting began as soon as fruits started ripening, and was

Fig. 5-1

Field Lay-out of Mocap Nematicide Trial

Design: 2 Varieties x 4 Level Factorial Exper.

with 4 Blocks in RCBD

BLK	I	T5	T6	T1	T7	T4	T2	T3	T8
BLK	II	T7	T3	T2	T6	T1	T4	T8	T5
BLK	III	T7	T4	T8	T6	T3	T1	T5	T2
BLK	IV	T8	T2	T6	T3	T5	T1	T4	T7

Where:

T1 is Napoli x 100 kg of Mocap/ha
T2 is Napoli x 25 kg of Mocap/ha
T3 is Napoli x 12.5 kg of Mocap/ha
T4 is Napoli x 0 kg of Mocap/ha
T5 is Roma VFN x 100 kg of Mocap/ha
T6 is Roma VFN x 25 kg of Mocap/ha
T7 is Roma VFN x 12.5 kg of Mocap/ha
T8 is Roma VFN X 0 kg of Mocap/ha

Plot Size = 15m x 1½m

pH = 5.6

Soil texture = Sandy loam.

Plate 7



Experimental plots at Hunkuyi where Mocap nematicide was tried on two tomato varieties: Napoli and Roma VFN.

completed about four weeks later. Plant roots from each plot were dug out and examined for the presence of galls. Only the Napoli variety showed any galling and these were assessed. At the 13th week of the application of the chemical, soil samples were taken from each plot for general nematode counts and identification of the Meloidogyne species.

5.1.2 Buruku Trial

The soil of the experimental plot at Buruku was sandy loam with pH 4.2. It had been lying fallow with heavy grass cover for seven months. The last crop had been tomato harvested in April, 1978, and it was reported to have had root-knot nematode infestation*. From July to October, 1978 (4 months) the area had been water-logged. The site clearing was early in December, and the experiment started two weeks later when harrowing was completed. Four levels of Mocap were applied and the tomato variety used was Napoli VF (a tomato variety susceptible to root-knot nematodes). The design was a 4 x 4 latin square. The nematicide levels were 200 kg/ha, 50 kg/ha and control (0 kg/ha). Plot size was 13m^2 each and there was one metre spacing between the plots. Before the application

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*Personal communication from Dr. Ratnam of the Ministry of Agriculture, Zaria.

of the nematicide each plot was sampled for the identification of active L2 and other plant parasitic nametodes present. The seedlings were transplanted at seven weeks old because the low temperature prevalent in December retarded their growth. Planting was done on the same day the chemicals were applied to the soil. By the fourth week after transplanting, the plants on the control plots were firmly established and were growing vigorously. Most plants growing in plots treated with the double dose of Mocap and a few in those treated with single dose were stunted, their leaves appeared smallish and crinkled, some of them actually withered off: this was no doubt a toxic effect of the Mocap chemical since similar symptoms had been observed in the seedbed experiments. Seven weeks later, however, the plants were apparently recovering and looked even better than the control plants. The control plants at this time already showed galling on their roots. No Meloidogyne larva was found in any of the samples initially examined before the soil was treated. A lot of non-parasitic nematodes were found. These included many Dorylaimida (the most predominant group) Mononchida, Rhabditida and a few parasitic species comprising Scutellonema, Helicotylenchus, Pratylenchus and

Criconemoides s.1.

Harvesting of the crop started 12 weeks after transplanting. Yields were generally high but about 40% of the fruit was unmarketable due to a heavy attack of fruit worm (Heliothis armigera) and fruit rot, the latter being mainly caused by the fruits lying low in the irrigation water.

5.1.3 **Government Residential Area site Trial**

The G.R.A. experimental site had the greatest number of active root-knot nematodes per liter of soil. The site was the tomato seedbed nursery of the Ministry of Agriculture, Zaria. The Ministry raised tomato seedlings here for the Galma Irrigation Scheme. The site was peculiar in that it is an upland site which had been left fallow the previous dry season and was put on maize sparsely intercropped with okra in the wet season, but still showed a heavy root-knot infestation. The soil was sandy loam and the pH was 5.4. The beds were prepared for our experiment after the seedlings had been removed, using the same beds again in order to ensure the availability of high nematode populations. Four levels of Mocap: 100 kg/ha (the recommended dose), 50 kg/ha, 25 kg/ha, 12.5 kg/ha and a control were applied. A tomato variety Roma VF was grown. The design was a Randomised Complete Block with 4 replications.

Soil samples were taken from each plot for the count of active L2. Mocap treatments were applied subsequently and the transplanting of seedling followed on the same day. The transplanted seedlings were already heavily infested with root-knot nematodes at the nursery. Bos (1979) was of the opinion that transplanting infested seedlings into uninfested soil would usually permit adequate growth of the plants because the newly formed roots are not immediately attacked again. Mocap applied, if effective, should provide such an uninfested soil for an adequate growth of the plants.

5.2.0 Results.

5.2.1 Effect of Mocap on Root Galling and Tomato Yield in Area of Scanty Root-knot Nematode Incidence (as at Buruku).

Table 5-1 shows the root-knot indices and the percentage effectiveness obtained from tomato at different levels of Mocap application. Mocap at 50 kg/ha and 100 kg/ha increased yields but not significantly over the control plants (Table 5-2). At 200 kg/ha level of application, Mocap decreased yields below that of the control plots (again not significantly). Perhaps any phytotoxic effects could have been avoided if sufficient time had

Table 5-1

Effect of Mocap Treatments on
Root-knot Infestation Indices of Tomato
(Buruku Trial)

Mocap Application Rate kg/ha	Mean Root knot Index	Treatment Effectiveness in %
0	3.61	-
50	1.73	52.0
100	1.74	51.8
200	0.82	77.3
	S.E. 0.15	

Table 5-2

Effect of Mocap Treatments on
Tomato Yield per plant (Buruku Trial)

Mocap Application Rate kg/ha	Mean Yield (g)	Yield kg/ha
0	1583	73
50	1831	85
100	1775	82
200	1558	72
	S.E. 174	

lapsed between the time of application and the transplanting of the seedlings, but such is not recommended by the manufacturer*. With regards to gall formation on the roots (Table 5-1) it is noteworthy that the chemical at 50 kg/ha and 100 kg/ha exerted the same degree of control. Even at the level as high as 200 kg/ha, galls were still formed on the roots at the end of the growing season. The effectiveness of the compound at this level, when compared to the degree of infestation in the control plants was 77%. What the plant could have gained by the decrease in galling is offset by the phytotoxicity of the chemical. The net effect is that the yields obtained from the plots treated with the "double dose" chemical is almost the same as those obtained from the control plots.

Both at Galma, and Buruku Irrigation Sites where similar nematode situations occurred, the land was left fallow for seven months (from May - November).

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*Mobil Chemical Tech. Bulletin on
Mocap No.10 1 September, 1973 p.1

For three months (August - October, 1978) the land had been submerged by flood water. Weeds predominant in the area were mainly Gramineae and Cyperaceae and those found are considered non-hosts to root-knot nematodes. Predominant were Panicum repens, Eleusine indica and Cyperus tuberosus. Thus the root-knot nematode population which had been built up during the previous growing of tomatoes probably was brought down by some natural factors during the subsequent fallow period.

5.2.2 Effect of Mocap on Tomato Yield and Root Galling in an area of low root-knot Nematode Population (as at the Hunkuyi Trial)

The yield results obtained at Hunkuyi where the Meloidogyne population was 310 per 100 cc of soil are shown in Table 5-3. With reference to the AOV table in Appendix 12 it can be seen that the chemical has not affected the general yields of the crops, the nematode - resistant Roma VFN had significantly higher yields than the susceptible variety Napoli. This may be due rather to varietal differences than effects of nematodes. The more or less uniform yields obtained

Table 5-3

Mean Yield of Tomato Plants following Soil Treatment with Mocap at Ifunkuyi

Cultivar	Dosage of Mocap in kg/ha	Mean Yield/plant (g)
Napoli	0	369.1 a
Napoli	12.5	385.9 a
Napoli	25	388.6 a
Napoli	100	454.2 b
Roma VFN	0	524.8
Roma VFN	12.5	536.7
Roma VFN	25	466.4
Roma VFN	100	526.2
	S.E. 9.2	

There is no significant difference in the mean with the same letter at P =.05 with L.S.D.

from Roma VFN in response to various levels of the Mocap treatments show that in this trial any phytotoxicity of the chemical has not affected crop yield. This is confirmed by the non-significance of the variety-chemical interaction analysis (Appendix 12). The variety Napoli on the other hand showed significant response to the different treatment levels; plants receiving full dose of the chemical produced significantly higher yields than those on lower levels of treatment - the control plants producing the lowest yields.

Table 5-4 indicates that Roma VFN showed no galling on the roots at all. The variety Napoli however, showed varying degrees of galling on the roots - the lowest galling appearing on the plants with full dose of Mocap treatment; mean galling indices increased with decreasing Mocap dosages, the highest occuring on the roots of the control plants. "Fisher's F-test" and the "Least Significant Difference" tests showed that the application of the chemical had significantly lowered the amount of galling formed on the roots.

Table 5-4

Root-knot infestation indices on
Napoli and Roma VFN Varieties

Treatment Mocap kg/ha	Mean Root-knot index on Roma VFN	Napoli
0	0	4.22 a
12.5	0	3.66 b
25	0	3.55 b
100	0	2.18 c
	S.E.	0.08
	L.S.D.	0.49

No significant difference in the figures having the same letter.

Table 5-5

Effect of Mocap Treatments on
Root Infestation Indices of infested
Tomato plants at 13 weeks old(Buruku)

Mocap application Rate kg/ha	Mean	Treatment Effectiveness in %
0	4.6 a	0.0
12.5	4.4 a	4.3
25	4.3 a	6.5
50	3.8 b	17.4
100	3.7 b	19.6

S.E. 0.27
L.S.D. 0.47
C.V. 9.05%

There is no significant difference in figures having the same letter.

There was a negative linear correlation between the yield of variety Napoli and the root gall index. A scatter diagram to this effect is shown in Fig. 5-2. The correlation of the two variables was found to be significant at 5% level (See appendix 17). At Buruku where the root-knots galling indices were lowest (Table 5-1) there was also a negative correlation with the yield though here it was not significant (Fig. 5-3).

5.2.3 The Effect of Mocap on tomato yields in an area with high root-knot nematode population (as at the G.R.A. trial).

The yields obtained from this site were generally poor, amounting to an average of 0.98 tonnes/ha (Table 5-6). Factors responsible are attributable to high nematode population in the soil, the use of infested seedlings, the phytotoxicity of the chemical used and temperatures.

The population of the active L2 found in the overall sample taken was 1310 per 100 cc of soil, and the mean count from the plots were 1050 per 100 cc of soil. Bearing in mind that other forms of Meloidogyne may also be present, this site no doubt had a high infestation of

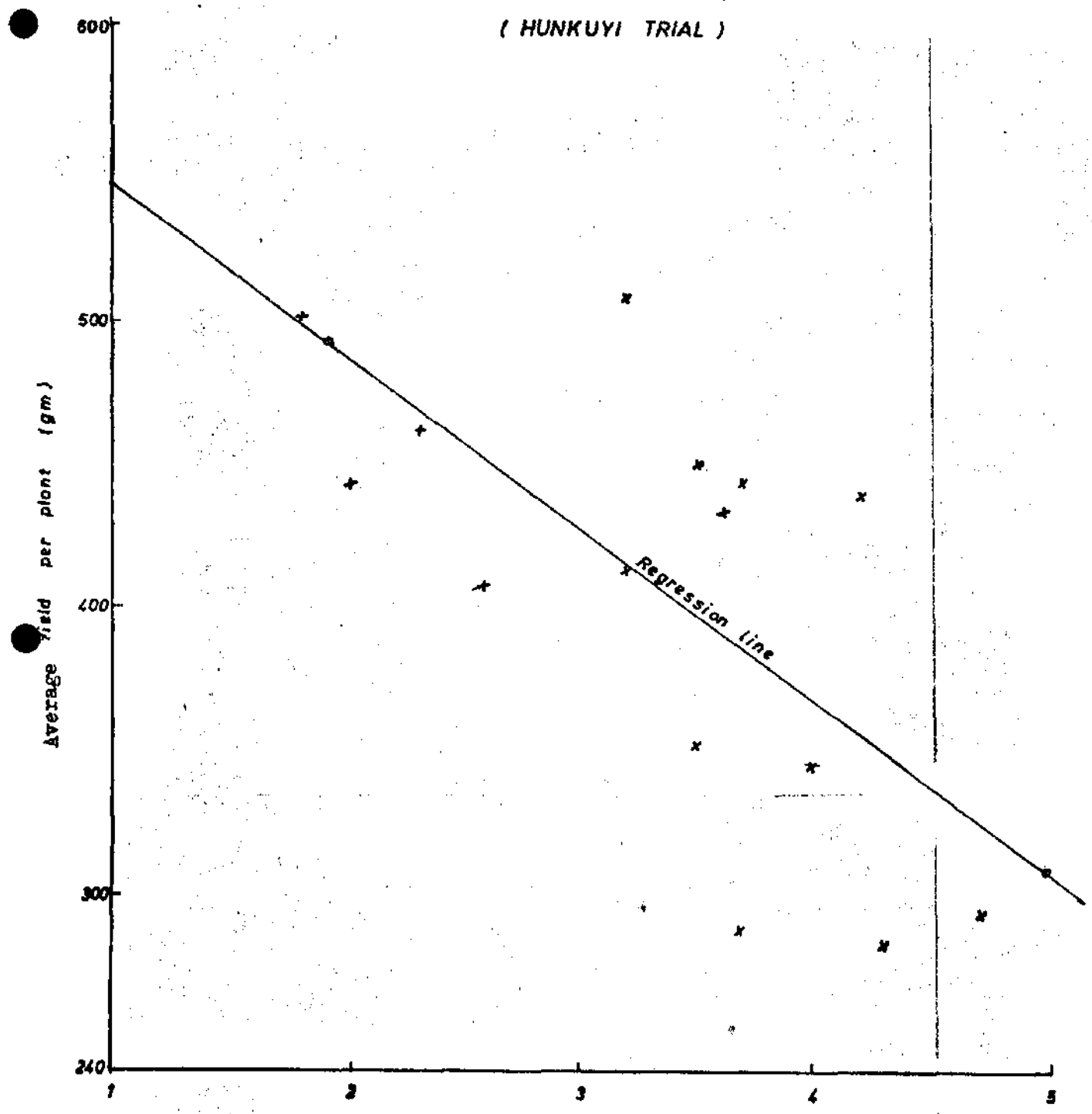
Table 5-6

Effect of Mocap on Tomato Yield in an Area with a high Root-knot Nematode Population

Mocap Application Rate kg/ha	Mean Yield per Plant (g)
0	167.0
12.5	194.7
25	109.6
50	153.6
100	104.8

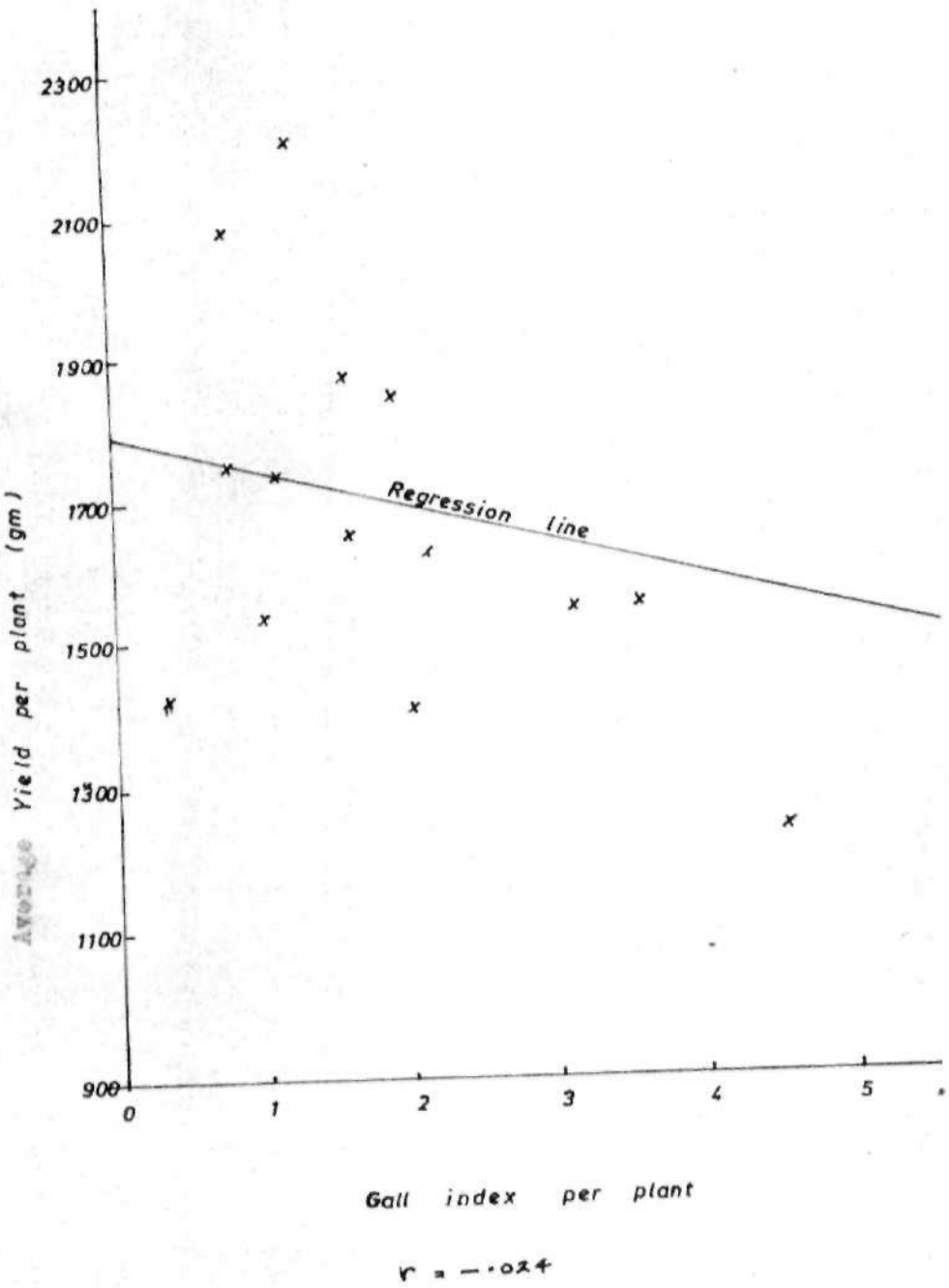
S.E. 40.6

FIG.5-2: FRUIT YIELD OF TOMATO PLANT PLOTTED AGANST ROOT-KNOT INDEX
(HUNKUYI TRIAL)



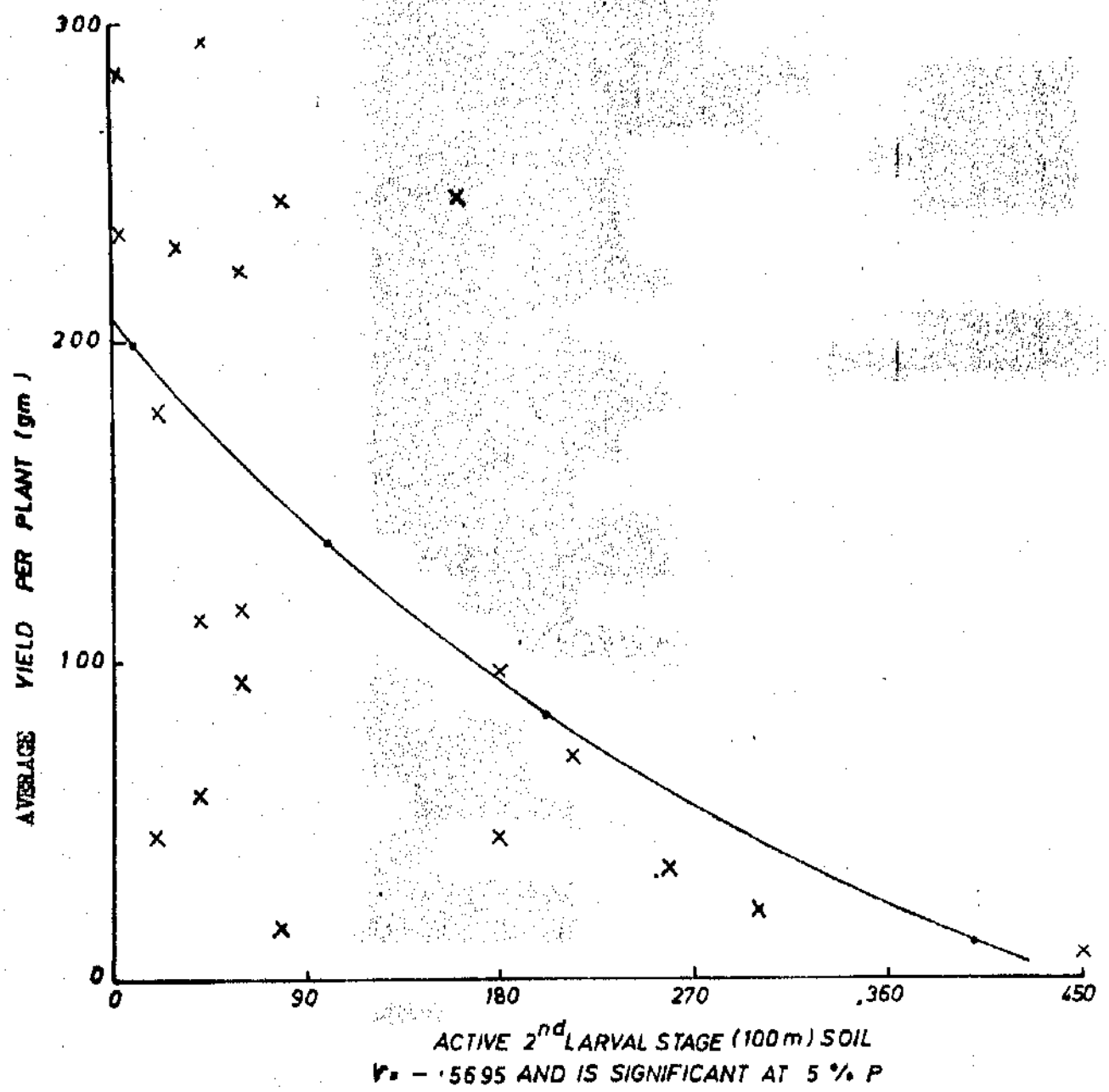
r =-.667 and is significant at 5% P

FIG 5-3. FRUIT YIELD OF TOMATO PLANT PLOTTED AGAINST ROOT-KNOT INDEX
(BURUKU TRIAL)



r = −·024

FIG. 5-4 FRUIT YIELD OF TOMATO PLOTTED AGAINST DENSITY OF ACTIVE 2nd LARV. STAGE OF MELOIDOGYNE SP.



$r = -0.5695$ AND IS SIGNIFICANT AT 5 % P

root-knot nematodes. Plate 8 shows the pattern of growth of infested ten-week old tomato seedlings on the site before the experiment. Growth was generally retarded and some of the plants were either dead or dying because of the heavy root infestation. A negative correlation was obtained when the yield was plotted against the active larvae counted plot by plot before the treatments (Fig. 5-4).

The use of Mocap on infested seedlings has apparently no significant effect on the development of the plants. From the galling indices shown in Table 5-5, it appears that the gall formation on the roots was generally high, irrespective of the treatments. Besides, the galls found in most of the roots were large and dark brown, suggesting that they were formed quite early in the plant life. So while Mocap has been found recently to be systemic in tomato roots (Argauer and Feldmesser 1978) it has not been able to kill the adult females sheltered within the root tissues, nor the next generation larvae. The seedlings were transplanted in February, Quinn (1974) has shown that tomato crops transplanted during January to May, produce yields which are

Plate 8



Seedling at 10 weeks old growing in a soil highly infested with root-knot nematodes. Some of the plants are either dead or are dying because of high root infestation.

very unsatisfactory between May and July. The factor largely responsible is the high temperature (night temperatures above 21°C and day temperatures above 32°C) which are considered deleterious for tomato growth, and fruit setting.

The yield data (Table 5-6) failed to bring out the effect of Mocap treatments at different levels. Although the yield quality has been shown to depend on several factors (such as mentioned above), the role of Mocap in this trial is inconclusive.

5.2.4 Effect of Mocap on other Plant Parasitic Nematodes.

The following species of nematodes were identified at Hunkuyi experimental plots:-

Aphelenchus avenae
Aphelenchoides app.
Helicotylenchus spp.
Hemicriconemoides sp.
Hoplolaimus pararobustus
Meloidogyne javanica
Scutellonema clathricaudatum
Xiphenema elongatum

Table 5-7 shows the effect of the chemical treatments on the nematode population 13 weeks after application. Mocap proved quite effective in reducing nematode populations. At the recommended dose of 100 kg/ha the nematode populations were reduced to one-third of the population in the control plots.

Table 5-7

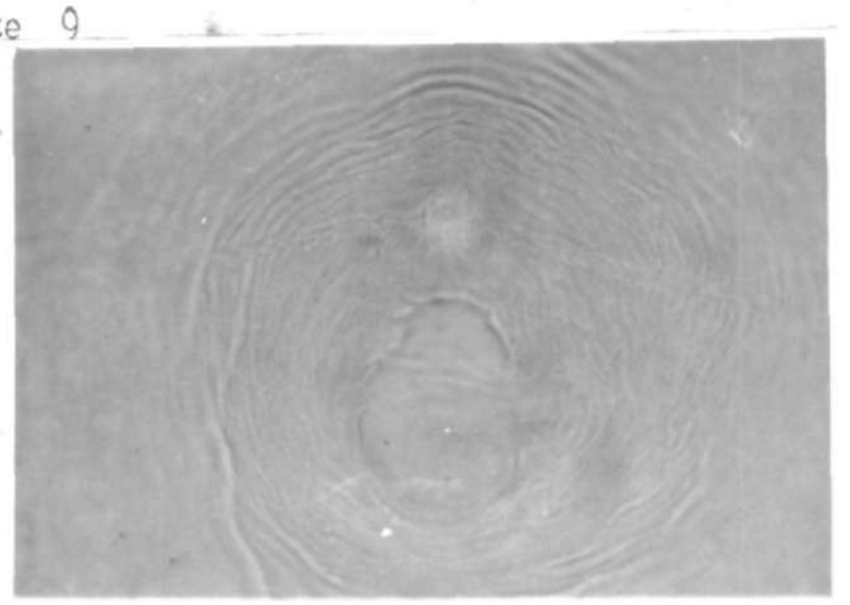
The Effect of Mocap Treatments
on the Mean Populations of all Nematodes
Species per 100 cc of Soil, 8 Weeks
After Application.

Mocap Application Rate kg/ha	Napoli-planted plots	Roma VFN planted plots	Mean	
0	1790	2350	2070	c
12.5	1380	1320	1250	b
25	1100	1050	1070	a b
100	750	560	660	a

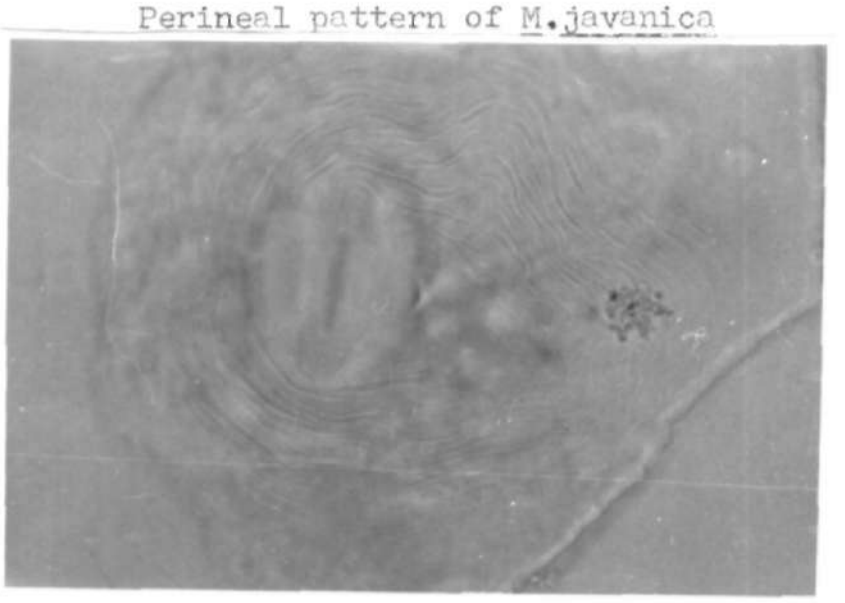
L.S.D. 510

There is no significant difference in figures having the same letters.

Plate 9



Perineal pattern of M.javanica



Perineal pattern of M.incognita

Meliidogyne spp. worked with. Mixed population of these species were found at Buruku, G.R.A., Hunkuyi and Samaru.

CHAPTER 6

Discussion and Conclusion

6.1 Summary of the performances of the chemicals.

In an attempt to find a substitute for Nemagon several Nematicides have been tested, notably: Nemacur, DD, Mocap, Basamid and Vydate. Mocap in particular was tried under both seedbed and field conditions because it was available at that time. Mocap, a non-fumigant organophosphorus compound was found to be rather phytotoxic to tomato plants under our conditions. This was true for dosages equal to or higher than that recommended by the manufacturers. (Recommended dosage being 10 kg a.i/ha). The phytotoxicity could be connected with the fact that in our rather acid soils hydrolysis of the chemical is slow. Mocap (10% granular) is however easy to apply by broadcasting and slight incorporation into the soil. The various rates of 25 kg (actual formulation) per hectare, 50 kg/ha, 100 kg/ha and 200 kg/ha respectively achieved 90%, 96.7% 97.5% and 100% effectiveness in root-knot control of tomato seedlings at 5 weeks. The same rate led to non-significant increase of 28.9%, 17.7%, 9.7% and 7.1% in fruit

weight respectively (Table 4-3). Mocap has very low efficacy in controlling root-knot or increasing fruit yield when applied to soils with high Meloidogyne infestation.

Nemacur is a systemic nematicide, active against ectoparasitic and endoparasitic, freeliving and cyst-forming nematodes.

It is a very effective nematicide. The application of 50 kg/ha (actual formulation) in our trial achieved 99.6% control of M.incognita. It is however a very toxic compound, having an oral LD50 of 15.3 mg/ha on male rats. It is therefore considered to be unsafe to recommend the compound to the peasant farmers at their present level of literacy and knowledge of agricultural chemicals. Even in larger farming enterprises like the new Irrigation schemes, which are largely manned by trained agricultural workers - cases of misuse of pesticides are quite common. The need to have people sufficiently trained in the use of agricultural pesticides, and only to allow such people to administer the chemicals when the need arises cannot be over emphasised.

DD is a fumigant compound whose efficacy has been known for quite a long time. In our experiment, DD effectiveness in preventing root-knot formation was shown to vary from 71.3% to 98.8% (Table 4-2), though the yield increase of tomato fruit 0.74% to 19% (Table 4-3) was not significant. The compound is however now allegedly being withdrawn from the market for health reasons like Nemagon was before. Even if it were not so, the application of DD to the soil would demand much labour and a certain skill from the farmer.

Basamid has a very broad spectrum of activity, it is effective against nematodes, soil fungi and weeds. Its effectiveness in root-knot control in seedbeds was very high, ranging from 75% to 99% (Table 4-2). The yield increase per plant by Basamid treatment were 8.6% to 40% (the latter being significant. Fig. 4-4). The chemical is however strongly phytotoxic, and soils treated with it do require a waiting period of three to six weeks before planting depending on the soil texture and moisture, it may even take a longer period during the rainy season. For the farmer it is definitely a great disadvantage if he has to wait that long before he can raise

his crop. Another disadvantage the compound has is the large quantity of it that is required. The standard recommendation by the manufacturer is 340 kg a.i/ha. It has been suggested (Caveness, 1971) that an ideal nematicide should be highly toxic to nematodes and give a satisfactory level of control at less than 5.5 kg a.i per hectare.

Vydate is also a systemic nematicide. It is very toxic with an acute oral LD50 of 37 mg/kg (actual formulation) for male rats. But the 10% granular formulation has a low dermal LD50 of 5000 mg/kg for rabbits. Vydate provides good control of a wide range of parasitic nematodes, and homopterous insects as well as when applied as a foliar spray. In the trial results (Table 4-3) Vydate was shown to be 97% effective in reducing root galling on tomato seedlings when applied at 1.4 kg a.i/ha (that is one-quarter of the recommended dose rate). Also at this rate a significant yield increase of 68% was recorded. The recommended dose (5.5 kg a.i/ha) gave an increase of 86% (Table 4-3). Vydate (in the 10% granular formulation) is easy to apply in normal farming situations. It can be spread easily and evenly

on the soil surface, be incorporated into the soil with simple hand tools and the crop can be planted immediately thereafter. But the chemical has no bactericide , and fungicidal properties.

From the foregoing characteristics of Vydate this nematicide appears to be the best of those we have tried in terms of effectiveness, phytotoxic risk, and ease of application. Its high oral toxicity not withstanding, at least the granular formulation is a relatively safe compound to handle if all necessary measures can be taken to avoid ingestion and inhalation. The only hitch however is the availability of the chemical. So far none of the chemicals used in the experiments has any dealer than can guarantee its availability in the country. But it should not be difficult to get one once a particular compound has been recommended and a market can be assured.

6.2 Measurement and Prediction of level of damage to tomatoes by root-knot nematodes.

Although damage by nematodes to crops can be monitored in the field it is difficult to eliminate other factors that my be interfering (like the presence

of other diseases, toxic effects of the chemicals used, etc). The difference between the actual yield and that which could have been obtained in the same field in the absence of nematodes cannot be determined reasonably accurately in this type of experiment. What we could have done but for lack of time, is to eliminate the root-knot nematodes from the same experimental fields, by growing non-host or resistant crops (like cotton and groundnut) for two or more seasons making sure that the weed hosts are suppressed. At the end another crop of tomato is raised on the site and the yield determined for comparison (compare 5-1).

It is obvious that a direct correlation between galling and severity of field infestation of root-knot nematode is not indicated, since in a poor crop root-knot indices may be very high but the nematode might not multiply on the poor or even dead root-systems. However, a correlation between galling index and yield is more likely and we tried to establish the correlations for our field trials at Hunkuyi. The correlation coefficient showed an inverse relationship

(r =-0.667) which is significant at 1% level of probability (Fig. 5-2). From the graph one can deduce that the tomato crop yield was reduced by a factor ranging from 15 - 40% (perhaps even better results could have been obtained if the data for the graph were based on individual plants affected by the nematode instead of the mean per plot that was used). In another result (from Buruku) such relationship was not significant (Fig. 5-2). It seems likely that the initial nematode level in this crop was much lower since the crop was raised on land that had been fallow and marshy for a long period (3-6 months).

6.3 Recommendation for Seedbed Treatment against Root-knot Nematode.

The ultimate purpose in controlling nematodes is to improve plant growth and development. Taylor (1959), Oteifa and Elgindi (1961) have reported that seedlings are the most vulnerable to nematode attack, so that if excessive attack during this stage is prevented, a good plant growth and yield can be expected. Therefore, the need for seedbed sterilization before raising such susceptible crops as tomatoes cannot be overemphasised.

The chemical that has proved most effective and convenient to use from our experiment is Vydate. But firm recommendation cannot be made yet based on a single trial. Mocap was phytotoxic when applied at planting time. In both Vydate and Mocap, the one-half to full dose of the chemicals as recommended by the manufacturer can give good control of the nematodes.

6.4 Suggestions for Further Work.

The root-knot nematode is ubiquitous in many Nigerian soils and attacks a large number of vegetable crops. Regretably, not much is known locally pertaining to the losses this nematode cause to the vegetable crops. Bridge (1972) gave for tomatoes an estimate of 40%, using the correlation between root galling and yield from Hunkuyi trial showed a loss of 15-40%. The use of root-knot indices has its own limitations and cannot be depended upon for an accurate representation of the nematode situation. An attempt was made to establish a correlation between counts of active L2 found at the beginning of the experiment and the routine fruit yield, and use the relation to determine losses. This method is not accurate either because it does not take into account the presence in the soil, of the inactive L2

and the root-knot nematode eggs which were not extractable by the method we used. An accurate evaluation method is therefore necessary to determine losses due to the root-knot nematodes.

Since Vydate is a systemic nematicide, and it has been shown by our experiment to be effective and convenient for use, it would be useful to determine how much residue remains in such vegetable crops as tomatoes before making recommendations to the farmers. Besides, more trials will be needed to confirm the good performance of the compound as shown in our results.

The results of the Mocap trial was not conclusive. Mocap was found effective in controlling root-knotting at seedlings stage, but it was phytotoxic when applied at the planting time. There is a need therefore to determine a suitable planting date after application which will remove the bottle-neck of the chemical phytotoxicity.

Appendix 1.

The Count per liter of soil per plot, of the 2nd stage of active Meloidogyne Larvae (Hunkuyi)

	B L O C K				
	1	2	3	4	
	500	200	400	300	
	100	200	300	800	
	200	500	200	0	
	400	200	200	300	
	100	300	200	300	
	100	200	600	400	
	0	600	400	1000	
	200	200	500	200	
	400	400	800	500	
	200	0	400	300	
	200	200	300	500	
	200	500	300	800	
	500	900	1100	800	
$\bar{X}$	238	338	438	477	$\bar{X}_1$=373.08

Larvae Count per 1000 cc of the general soil sample before soil preparation = 3200

Appendix 2.

The Count per 1000 cc of soil

per plot, of the 2nd stage of active larvae

(Samaru)

B L O C K				
1	2	3	4	
300	400	100	300	
8900	600	800	300	
800	0	200	2500	
400	600	1600	500	
200	200	300	200	
3200	100	300	100	
6200	1400	200	200	
1700	0	1400	-	
4000	300	700	0	
200	1100	0	2600	
200	500	400	0	
100	0	900	0	
0	100	2900	300	
400	300	100	800	
0	4100	1000	200	
600	600	0	1700	
900	200	1300	9700	
800	3700	0	0	
$\bar{X}$ 1406	788	678	2100	$\bar{X}_2$=105.2

Appendix 3.

The Count per 1000 cc of soil per plot of the 2nd stage active Meloidogyne larvae (GRA)

B L O C K

1	2	3	4	
600	800	3000	2600	
200	2200	200	1800	
300	400	4500	200	
1600	400	600	500	
0	0	400	600	
$\bar{X}$ 540	760	1740	1140	$\bar{X}_3$=1045

Appendix 4.

Analysis of Variance for root galls per plant in four nematicides trial (at Hunkuyi)

Design: 4 x 4 Randomised complete Block Design (RCBD)

Sources of Variance	D.F	SS	Mean Squares	F Calculat.	F Tabulated
Block	3	.124	0.041	1.76	2.84
Treatments (Treats)	12	1.393	0.116	4.979*	2.00
Error	36	.838	0.0233		
Total	51	2.355	-		

*Significant at 5% P.

Appendix 5.

Analysis of Variance for root gall index per plant in four Nematicides trial(Samaru)

Design: 4 x 4 (RCBD)

Sources of Variance	D.F	SS	Mean Squares	F Calculat.	F Tabulated
Block	3	.03021	.01007	1.2	2.20
Treats	17	2.308	.1358	16.134	6.10*
Error	51	.029	.0084		
Total	71	2.768			

Coefficient of Variation = 11.14%

*Significant at 5% P.

Appendix.6.

Analysis of Variance for tomato
Seedling height at 5 weeks (at Samaru)

Design: 4 x 4 (RCBD)

Sources of Variance	D.F.	SS	Mean Squares	F.
Block	3	51.154	17.051	2.20
Treats	17	805.968	47.409	6.10*
Error	51	396.131	7.767	
Total	71	1253.252		

*Significant at 1% P.

Appendix.7.

A.O.V. for Yield

Sources of Variance	D.F.	SS	Mean Squares	F.
Block	3	93154.900	31051.633	1.06
Treats	17	1.10	64921.389	2.22
Error	51	1.49	29205.788	
Total	71	2.69		

*Significant at 5% P.

Appendix 8.

Analysis of Variance for root gall index of tomato plant at 12 weeks

Sources of Variance	D.F.	SS	M.S	F.
Block	3	.20914	.0697	.84
Treats	17	10.8301	.637	7.70*
Error	51	4.2217	.0827	
Total	71	15.2609		

CV = 22.8

*Significant at 1% P.

Appendix 9.

Analysis of Variance for yield of Tomato in low level Nematode infested Soil (At Buruku)

Design: 4 x 4 Latin Square

Sources of Variance	D.F.	SS	M.S.	F	F (.05)
Rows	3	1.04	345520.06	5.67	
Colums	3	28820.681	9606.896	1.16	
Treats	3	223106.19	74368.729	1.22	3.86
Error	6	365390.87	60898.479		
Total	15	1.65			

Appendix 10.

Analysis of Variance of root gall infestation index at 13 weeks of transplanting (at Buruku)

Sources of Variance	D.F.	SS	MS	F	F (0.5)
Rows	3	1.143	.381	1.09	
Columns	3	0.305	.102	.29	
Treats	3	16.476	5.492	15.719	3.86
Error	6	2.096	.349		
Total	15	20.021			

*Significant at 5% P.

Appendix 11.

Table of Average yield per plant of Napoli and Roma VFN Tomato (Hunkuyi trial)

	Napoli Var.				Mocap	Roma VFN Var.		
BLOCKS	100kg/ha	25kg/ha	12.5kg/ha	0	treat. 100kg/ha	25kg/ha	12.5kg/ha	0
I	501.68	411.89	506.92	438.96	646.38	533.41	463.18	661.03
II	463.29	449.39	432.24	441.16	597.44	583.24	582.06	597.67
III	492.97	345.51	325.56	282.35	419.53	375.46	462.64	448.14
IV	408.91	347.56	284.75	313.78	441.62	373.39	639.09	392.35
V	454.21	388.59	385.87	369.06	526.24	526.24	536.74	524.79

S.E. 9.17

Table 12.

Analysis of Variance for yield of
the Napoli and Roma VFN Varieties treated with Mocap

Design: 2 Var x 4 level fac. exp. with 4 blocks in RCBD

Sources of Variance	D.F.	SS	MS	F	F
Blocks	3	125669.0	41889.66	10.946	3.07
Chemicals	3	17759.0	5919.66	1.547*	3.07
Varieties	1	104159	104159.0	27.22**	4.32
Variety-Chem. Interaction	3	11343.5	3781.166	0.988*	3.07
Error	21	80364.3	3826.87		
Total	31	339294.8			

* Not significant.

** Significant at 5% P.

CV = 13.56%

Appendix 13.

Analysis of Variance for root gall
index of Napoli infected plants (at Hunkuyi)

S O V	D.F	SS	MS	F
Block	3	0.83	0.276	3.0
Treats	3	9.06	3.02	32.83*
Error	9	0.83	0.092	-
Total	15	10.72	-	-

*Significant at 5% P.

Appendix 14.

Analysis of Variance for
Nematode Population at 12th week of
Transplanting (Hunkuyi)

S O V	D.F.	SS	M.S	F
Block	3	9672.25	3224.08	1.33
Treats	3	88419.0	28139.66	11.63*
Var	1	363.0	363.0	
Error	24	58081	242004	
Total	31	152614		

*Significant at 5% P.

Appendix 15.

Analysis of Variance for the
root infection index/plant of tomato plant at
13th week of transplanting(GRA)

Design: 4 x 5 RCBD

S O V	D.F.	SS	M.S	F
Block	3	2.741	.914	6.49
Treats	4	2.586	.646	4.59*
Error	12	1.690	.141	
Total	19	7.017		

C.V. = 9.05%

*Significant at 5% P.

Appendix 16.

Analysis of Variance for yield of tomato treated with Mocap under high level of infestation

S O V	D.F.	SS	MS	F	F
Block	3	16.489	5.496		(.05)
Treats	4	7.039	1.759	1.28	3.26
Error	12	16.531	1.377		
Total	19	40.059			

C.V. = 25.9%

Appendix 17.

Regression Analysis: Effect of Root galling on fruit yield of tomato (Hunkuyi trial)

S O V	D.F.	SS	M.S	F	Sig.
Regression	1	34814.55	34814.55	11,012	0.005
Residual	14	44259.26	3161.38	-	-

Constant a = 593.5715
b = 57.09457

Appendix 18.

Soil Temperature and Day length records
at Samaru for months of December 1978 and Jan., 1979

Day	December, (1978) Earth Temp°C 5cm	Earth Temp°C 30.5cm	S/Shine hrs/day	January, (1979) Earth Temp°C 5cm	Earth Temp°C 10.5cm	S/Shine hrs/day
1	24	23.6	10.4	22	23	8.9
2	24	23.5	7.3	22	23	7.8
3	24	23.3	9.8	21	22.5	8.1
4	24	23.3	9.7	21	22	8.8
5	24	23.3	10.1	21	22	4.7
6	24	23.5	10.3	21	22	7.0
7	24	23.5	10.1	21	22	8.1
8	24	23.5	8.8	21	22	9.3
9	23	23.6	9.4	21	22.4	9.0
10	22	22.8	8.0	21	22.2	8.8
11	23	22.5	7.0	22	22.4	7.8
12	22	22.5	6.9	22	23.0	7.3
13	22	22.5	7.4	21	22.7	9.9
14	22	22.5	9.4	21	22.4	10.1
15	22	23.0	9.4	23	23.0	9.9
16	22	22	9.8	23	23.0	10.0
17	21	22	10.0	22	23.5	9.5
18	22	22	9.6	23	23.0	9.9
19	21	22.5	8.9	22	23.0	6.4
20	22	22	9.6	21	23.0	6.4
21	21	22	10.0	22	23.0	10.0
22	22	22	9.9	22	23.0	10.0
23	22	22	9.4	22	23.0	8.2
24	22	22.5	10.4	23	23.0	9.4
25	22	22.4	10.1	22	23.0	10.0
26	23	22.4	9.3	22	23.0	9.8
27	21	22.5	8.8	25	23.5	9.5
28	22	22.5	6.1	24	24.0	10.7
29	22	22.5	8.9	23	23.5	10.5
* 30	23	22.3	8.3	22	23.5	9.8
31	22	22.3	6.3	22	23.5	10.2
Tot.	698	702.8	279.4	681	708	275.8
Mean	22.5	22.7	9.0	22.0	22.8	8.9

* Date of sowing Mocap and Vydate-treated plots.

** Date of sowing DD and Basamid-treated plots.

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