CHAPTER II

REVIEW OF LITERATURE
Adherence of Pesticides

Pesticides differ in their ability to adhere to a treated surface. It is usually considered that the smaller the particles of a pesticide deposit, the greater its tenacity. However, Heuberger (1942) did not find difference in adherence of 0.5 and 0.2 micron particles that were otherwise identical. Decker et al. (1956) observed that toxaphene and chlordane leaving waxy or sticky deposits adhered more effectively than those that left crystalline deposits such as DDT.

Srivastava (1955) found that significant increase occurred in the coating as the concentrations were increased. The rates of increase of various pesticides were not uniform and 'Seed Guard' gave the highest coating to different varieties of cereals than lindane, heptachlor or aldrin as dry seed dressing.

Starks and Lilly (1955 a) in their studies of insecticidal seed treatment to soybean found that the combination of lindane with the fungicides somewhat increased seed coat adherence. These authors in a further publication reported that methyl cellulose as sticker was superior to dry application of lindane, since it gave an even coverage leading to reduced seedling injury at higher dosages of lindane (Starks and Lilly, 1955 b).
Generally, methyl cellulose is dissolved in water to make 2.5 to 3 per cent solution to act as sticker involving liquid applications (Reynolds, 1956). Metcalf and Flint (1962) mentioned that the use of dusts impregnated with oily materials, was sometimes of advantage in increasing deposits. Moreover, several materials such as casein, gelatin, soybean flour, blood albumen, various clays, bentonites, petroleum and vegetable oils were mentioned as stickers to increase adherence.

Hoskins (1962) while reviewing some important properties of pesticide deposits on various surfaces has also summarised that dusts are often highly charged and their adhesion to a surface is partially controlled by electrostatic forces, whereas in case of spray particles, it occurs to a much smaller degree.

Ebeling (1965) in a critical review analysed the various basic processes involved in the deposition of pesticides and noted that various factors like size, shape of particle, the size spectrum, the chemical and physical properties of the diluent and the adjuvants to a great extent determine the variations in the actual quantum of the dust deposited on the treated surface.

Griffiths et al. (1970a) tested wheat seed dressings with four organophosphorus compounds in standard siliceous earth formulations to compare with
special formulations of the same compounds in polyvinyl acetate, polypropylene or wax. The special formulations allowed more insecticide to be placed on the seed. In another study, Griffiths et al. (1970 b) dressed the winter wheat seeds with powders containing an organo-mercury fungicide mixed with gamma BCH, chlorfenvinphos or ethion. The results analysed by gas liquid chromatography revealed that the ethion dressing adhered to the seed considerably better than chlorfenvinphos dressing or than gamma BCH alone or combined with the fungicide.

Lord et al. (1971 a) analysed the commercially dressed cereals, mostly wheat to work out the retention and distribution of pesticides. They found that the average loadings of seeds treated with dry powder formulation were nearly always small, but the distribution of insecticide between seeds was fairly uniform. Insecticides applied as dry powders did not adhere strongly to the seeds but they remained in association with the seeds contained and carried in bags. On the other hand, the average loading of seeds treated with liquid formulation was closer to the target, but the distribution was irregular, most of the seeds carried little insecticide and few seeds carried amounts large enough to be phytotoxic.
Investigations on the effect of insecticide-fungicide combination on adherence to the wheat seed were done by Griffiths et al. (1972). They observed that the combination of powder fungicide and liquid insecticide, greater amounts of pesticide on the seed were obtained if the insecticide was out on first.

Baciu and Diaconu (1972) determined the adherence of pesticide products to seed given as dry treatment. They observed that out of the insecticides and insecticide-fungicide mixtures used in the experiments, the best adhesiveness was that of PEI-120, PEB and TB2 on wheat, benlate on sugarbeet and quinoate V-4-x on flax seed. The adhesiveness on the seeds depended, primarily on their size, as smaller seeds retained larger amounts of pesticides. The successive handling of the dressed seeds resulted in important losses of pesticides.

Large quantities of powder may be applied with the use of adhesives as evidenced by Jeffs (1973) and Jeffs and Walker (1973), since in the laboratory systemic fungicide formulations were applied successfully at the rate of 16 g of 50 per cent powder per kg of barley seed. This dosage would give a loading of 640 ug of powder per single seed.
The adhesion of the powder was greatly increased when wheat seed and a powder formulation were vigorously mixed for long enough (Jeffs, 1976). This was because the particles were distorted to give an increased area of surface contact. The particle size of the powder also affected its adhesion, perhaps a certain size of particles were easily entrained by the irregular parts of the surface. Jeffs and Tuppen (1978) in an article dealing with the application of pesticides to seeds have mentioned that adhesion of particles to a surface is a complicated process brought about by many factors, from molecular forces to physical trapping of small particles. In the absence of adhesives on the seed or in the formulation, adhesion is due almost entirely to physical trapping, by beard and wrinkles on the surface of wheat seed.

**Effect on germination and growth**

Phytotoxicity to the crop is a major consideration while applying the pesticides in the soil or in the development of seed treatment. Maximal phytotoxicity is manifested by non-germination of a seed or other symptoms of variable categories like, delayed germination, retarded growth, atypical growth or plant injury. Most agricultural crops appear to show a fairly high degree of tolerance to recommended dosages of soil insecticides.
(Fleming, 1948; Foster, 1951; Cox and Lilly, 1952; Fleming and Maines, 1953). Any treatment which places the chemical involved in as intimate contact with the seed and tender germinating plant parts, as seed treatment may cause plant injury (Reynolds, 1958). When prophylactic treatments are applied, phytotoxicity can not be tolerated.

Hays (1920), in an attempt to control Solenopsis molesta Say, tried kerosene, turpentine, nicotine sulphate, oil of lemon, camphor, crude and refined carbolic acid and two brands of commercial chicken dip, composed largely of crude carbolic acid and creosote as seed treatment. He found that many of them were detrimental to the germination of seed. Many early attempts have mentioned adverse effects with the use of chlorinated hydrocarbons, mainly the BHC, DDT and lindane in several garden and field crops, particularly the vegetables (Morrison et al., 1945 a,b; McLeod, 1946a,b; Arnesson et al., 1947; Brooks and Anderson, 1947; James and Anderson, 1947; Fleming, 1946; Morrison et al., 1948; Stoker, 1948; Kostoff, 1948, 1949; Lange et al., 1949; Foster, 1951; Fleming and Maines, 1953; Elmore, 1953; Gould, 1955; Starks and Lilly, 1955a,b). Of the grain crops sorghums are among the most sensitive (Cox and Lilly, 1952).
King et al. (1948) reported that for cereal crops, especially wheat, treating the seed with special concentrated preparations of BHC showed great promise against wireworms. He, however, did not recommend it for general use until more is known regarding possible injury to seed or seedlings. Fleming (1948) reported that barley and wheat grew normally in the soil treated with 25 lb of technical DDT per acre.

Kostoff (1948, 1949) treated the seeds and seedlings of certain plants with hexachlorocyclohexane and found cytogenetic changes and atypical growth in the seedlings. In gramineous plants the insecticide induced atypical growth suppressing the development of the roots, stem and coleoptile and causing striking thickening of these organs especially the growing points.

Gullinan (1949) found depressed growth of some seedling plants when DDT, BHC, chlordane and toxaphene dusts were applied to soil at 25 lb, per acre. Root systems were injured more by BHC and chlordane than by DDT. In vegetables, chlordane was toxic to seedling plant than BHC. It severely affected germination at 25 lb per acre. With BHC emergence was affected but not the germination. Injury to plants was noted on soils low in organic matter.

Hocking (1949) treated seed wheat with various preparations and constituents of BHC to observe the
effects on germination and development. He evidenced that plant deformation was not due to gamma isomer but caused by a mixture of trichlorobenzene and relatively small doses caused inhibition of germination. In further investigations (Hocking, 1950), it was noted that all the plants grown from wheat seed treated with crude BHC showed browning and swelling of the root tip, shortened roots, absence of root hairs, and a shortened, thickened and flattened coleoptile but the symptoms were less pronounced in case of pure gamma BHC. In a further series of tests it was confirmed that trichlorobenzene prevented germination at the higher doses and retarded it at the lowest dose. Even the seeds of some varieties of wheat, oats and barley exposed to different isomers of trichlorobenzene caused total or partial failure of germination, or greatly retarded growth.

Primosi (1950) observed that when barley, rye, wheat and oats were dusted with 0.1 and 0.2 per cent 'Gesarol' containing 10 per cent DDT and planted in sand 10 days later, germination was not affected by the lower rate. But with the higher rate, percentage of viable seed was slightly reduced, the time required for germination increased and subsequent root development was inhibited. In case of barley the adverse effects were negligible.

Faber (1951) discovered that germination of seed wheat was somewhat stimulated by soaking in BHC emulsion.
Jameson and Callan (1951) treated wheat, barley and oats seed with 'Mergamma' containing organomercurial and gamma benzene hexachloride at various rates. They found that levels of gamma benzene hexachloride, safe in practical tests in the field and in the box tests in soil, were markedly phytotoxic in conventional germination tests in sand or on damp filter paper. A dose of 250-500 ppm caused checking and thickening of the shoot and characteristic clubbing of primary roots and the doses above 500 ppm led to suppression of normal growth.

Phytotoxic effect of seed dressing under different soil and climate using 20-70 per cent gamma BHC on winter oats and wheat were observed by Jameson et al. (1951). Concentration of 20-30 per cent gamma BHC slightly retarded the appearance of the seedlings above ground but the effect disappeared after a few days, at 70 per cent, the growth was seriously retarded. In laboratory tests of the effect of overdressing, germination of seed treated with 70 per cent gamma BHC at 2 oz or 35 per cent at 4 oz per bushel was delayed.

Cox and Lilly (1952) investigated the effects of aldrin and dieldrin on germination and early growth of field crop seed in green-house. Insecticide levels ranging from 2 to 128 pounds (technical) per acre were taken for barley, buckwheat and winter wheat crops.
Barley was found to be more tolerant than wheat to aldrin. Dieldrin did not cause any severe adverse effect on germination or average green plant weight in both these crops. However, in general on wheat, aldrin at higher doses caused decreased per cent emergence, drop in average green weight and some deformity of plant growth and chlorosis.

Frost et al. (1954) determined the effects of dieldrin and lindane, and of certain fungicides upon the emergence of seedlings of green peas, spinach, onion, cotton and nine varieties of cucurbits. They observed that when insecticides were used without a fungicide, the seed was more predisposed to injury by decay organisms, and plant emergence was often less than in untreated plots. Lindane and thiram combination gave better seed protection than other treatments.

Srivastava (1955) evaluated six chemicals (insecticides and insecticide-fungicide formulations) as seed treatment on some cereals. In general 'Seed guard' produced a beneficial effect on the germination of most of the cereals tested. Pawnee wheat sustained a germination injury when treated with Panogen, PL-1 and also gave a highly significant root-top ratio than all the other treatments.
Starks and Lilly (1955 a) in their studies of insecticidal seed treatment to soybean varieties, observed that high dosages of BHC did not affect large reductions in total emergence or mean green weight under green-house conditions. Starks and Lilly (1955 b) while investigating the effects of seed treatment on dent corn observed deficiencies in green weight caused by high dosages of lindane.

McIwen et al. (1957) compared the relative effectiveness of various insecticide-fungicide seed treatments on lima beans. Freshly treated seeds with both insecticide and fungicides or with fungicides only resulted in about 90 per cent stand, untreated seed and that treated with aldrin or gamma BHC alone in about 70 per cent stand, and that treated with diazinon alone in about 50 per cent.

The findings of the termite research scheme at Anand (Varwala, 1956-57) concluded that the seed treatment of wheat with BHC as with other insecticides did not give any better germination or better stand or increased yield.

Chatterji et al. (1958) conducted trials by using DDT, BHC, toxaphene and dieldrin dusts in the soil before sowing upto 2C lb per acre against termites in wheat crop. They did not observe significant difference in tillering by various insecticides as compared to control.
In the trials conducted by Bindra (1960), dusts and wettable powders of several insecticides were mixed with wheat seed for the control of termites. BHC, lindane and chlordane affected germination and inhibited growth. Aldrin and dieldrin gave complete protection against termites and appeared to stimulate growth and tillering and hasten maturity.

Patel (1962) reported that a higher dosage of BHC (4 lb of 50 per cent BHC per 112 lb seed) in seed dressing was harmful to germination of wheat crop. Similarly, Reddy (1962) also indicated about the reports of adverse effect of BHC on the root formation of certain cereal crops. While, Ghosh (1964) with the pre-sowing soil treatment of aldrin, chlordane and BHC at the rate of 3.4, 2.27 and 3.4 kg a.i. per hectare did not observe adverse effect on germination and growth of wheat crop. Instead, phytostimulation due to aldrin treatment was noticed.

Bowling (1964) conducted studies on the germination and emergence of rice seed treated with three formulations of aldrin at two different rates. Fifty and seventy five per cent wettable powder at the rate of 4 and 8 oz a.i. per 100 lb of seed caused little or no detrimental effect on germination and emergence of seedlings. A liquid formulation (4 lb a.i. aldrin per gal) at both the 4 oz and 8 oz a.i. rates caused greater reduction in germination.
and emergence. In further investigations, Bowling (1965) treated seed rice with various insecticides and fungicides alone and in combination with each other to study the effect on germination and emergence, and seedling number and larval population of rice water weevil *Lissophoptrus oryzophilus* (Kuschel) in small plots. Aldrin liquid or endosulfan liquid showed a greater reduction in germination than the other treatments with wettable formulations. Thiram exhibited phytotoxic effect in the germination test. All the treatments except endosulfan liquid produced growth (seedling height) equal to or significantly better than the untreated check. In the emergence and small plot tests the results were reversed, and the treatments with thiram produced the best results. None of the data indicated incompatibility between insecticides and fungicides.

Sahni and Butani (1966) got very good germination and yield when wheat seed was treated with aldrin emulsion. They also observed the superiority of seed dressing with Dic dust and wettable powder (doses not mentioned) over the control as evidenced by better germination and higher yield.

Sachan et al. (1967) applied four insecticides viz., aldrin, BHC, chlordane and dicloran to the soil at three different dosages to study their effect on emergence
tillering, leaf number and height of wheat plants. Aldrin delayed emergence as the dosages increased except at 3 lb a.i. per acre. BHC treatment showed no significant retardation in seedling emergence. Dieldrin showed significant increase in final emergence. Chlordane was observed to be highly toxic to germinating seedlings. There was no significant effect on height, tillering and leaf number except in chlordane treated plants.

Durand (1967) evaluated eight compounds as seed coating for the control of *Mayetiole* spp. on wheat. Gamma BHC at higher rates of application afforded better control, but adversely effected germination.

Seed dressings of organophosphorous and carbamate insecticides at 0.1 and 0.5 per cent toxicant by weight of seed were compared with heptachlor and ethion for the control of wheat bulb fly by Griffiths et al. (1969). During these trials the authors observed that chlordiphos and bromophos-ethyl at both rates and B 80833 at the higher one damaged young seedlings. There was only slight damage with phoxim at the higher rate and none with primiphos-ethyl.

Mishra and Chand (1970) tested twelve fungicides for seed treatment against *Sclerotium rolfsii* of wheat.
They found that Tritisani, Brassical and thiram promoted best seedling vigour and root development. Gupta and Mishra (1970) reported that seeds of mung sown in clay loam soil treated with carbarb at 5 to 50 ppm adversely affected the germination particularly at higher dosages. Different results were obtained by Griffiths et al. (1970 b) in different soils with gamma HCH treatment to wheat and doses up to about 50 ug per seed did not affect germination in peaty loam soil. However, all gamma HCH treatments in sandy loam soil adversely affected germination. Although insect control improved with the increased loading of insecticide but untreated seed gave better scores for plant vigour than any insecticide treatment even after insect attack.

Allen (1971) evaluated six promising materials for the control of a cereal borer, Dasiantha caudata Pasc. and their effect on germination and plant growth of wheat. Those applied as seed dressings with the weight of toxicant per bushel seed, were phosalone or methomyl (both at 2 and 4 oz, methomyl at the higher rate alone or with a fungicide), endosulfan (4 oz) and diazinon (3 oz). Methidathion and chlorfenvinphos were applied with superphosphate at 8 and 6 oz toxicant per bushel, respectively. All the insecticides except endosulfan reduced the number of germinating seedlings, methomyl to a greater extent
at the higher rate especially when combined with a fungicide. Where plant numbers were reduced, the number of tillers produced after 172 days either exceeded or did not differ significantly from the number produced by untreated plants. Endosulfan, phosalone and methomyl at the lower rate were sufficiently promising to warrant further tests.

Balcu et al. (1971) in their studies on the seed treatment of cereals with fungicides and mixed products in Romania found that only pyracarbolate caused phytotoxic effects.

Wheat seeds of varieties C-306 and Kalyan-227 with BHC wettable powder at the rate of 0.05-0.25 kg a.i. as dry and wet treatment, and with aldrin emulsion concentrate at the rate of 0.1-0.75 kg a.i. per 40 kg seed were tested by Verma et al. (1971). They found that except BHC dry at the rate of 0.05 a.i. all the treatments reduced the viability of seed. The reduction in germination varied from 1.6 to 84 per cent in various treatments. There was no difference in the performance of both the varieties to any treatment. BHC wet treatment was more destructive than BHC dry and aldrin treatments.

Dalvi et al. (1972) in their results on the influence of pesticides on mungbeans and wheat seeds indicated that
various concentrations of menazon, disulfoton and GS-14254 inhibited germination and were also considerably effective against seedling growth. It was also noted that the seedlings surviving the pesticide treatment were distorted and weak. The degree of inhibition of germination of seeds and seedling development depended on the concentration of the chemicals. The effects were more pronounced in wheat than in mungbeans.

Griffiths et al. (1972) studied the biological effects of combining carboxin, organomercury fungicides and insecticides (aldrin, carbofuran, phos as liquid formulation or a gamma BHC powder formulation) as seed dressings for wheat. They found that gamma BHC with organomercury fungicide decreased the number of plants that germinated and gamma BHC with carboxin and organomercury was even more deleterious.

Ozkan and Finci (1974) while using certain pesticides observed that preparations containing gamma BHC applied as seed dressings to wheat either dry or with 1.5 percent water, many of the seeds that did not germinate gave rise to malformed plants. Additional tests with eight varieties of wheat showed that gamma BHC even at an application rate of 0.02 percent affected germination and seedling shape regardless of the wheat variety concerned. The somatic chromosomes in the root-tips mitoses were analysed by Zeller and Hauser (1974) after
treatment of barley, rye, summer wheat and oats with seed
dressings containing gamma BHC. Most of the chromosome
sets in the root tip cells were found to have been
polyploidised. Tests with pure gamma BHC showed that
this insecticide was responsible for the induction of
polyploidy.

Verma (1974) studied the effect of seed treatment
with BHC and aldrin dusts on germination using wheat seed
of variety C-306. He documented that wetted seed dressing
with aldrin dust even at the highest dose of 1.5 kg a.i.
(10 kg of 5 per cent) per 40 kg seed had no adverse
effect on the germination of wheat seeds. Whereas, in the
case of BHC the percentage germination obtained with C.05
and 0.1 kg a.i. doses was comparable with the control and
any further increase in the dose adversely affected the
germination. In fact with doses from 0.5 kg to 1.0 kg
a.i. of BHC, the germination was almost negligible.

Verma et al. (1974) in a trial on the effect of BHC and
aldrin on termite damage in irrigated wheat crop, where
insecticides were applied by different methods, found
that wheat seeds treated with BHC at the rate of 1.25-2.5
kg a.i. per hectare did not germinate. Though the
observations were not recorded, it was however, noted
that seed dressing with aldrin at the rate of 1.875 kg
a.i. per hectare brought about a negligible reduction in
germination. Verma et al. (1979 a) treated the wheat
seed obtained after threshing with BHC 10 per cent or malathion 5 per cent dust @ 250 and 125 ppm a.i. respectively, and then stored. Subsequently, germination observations recorded after 21 days of sowing in 1973-74 and 1974-75 revealed the germination of treated seeds as good as that of untreated seeds. In trials on barley Verma et al. (1979 b) found that none of the aldrin and BHC soil or seed treatments improved germination over control during three years of experimentation. However, during 1975-76 aldrin 30 e.c. at the rate of 15 and 20 ml per kg seed adversely affected the germination.

Chemical control of termites

The chemical control of termites for the protection of wheat and barley crops involves a four pronged approach viz., soil treatment, seed treatment, post-sowing treatment with irrigation and mound treatment, of which the latter three are reviewed here in view of their direct bearing with the present line of investigations.

Seed treatment:

David and Gardner (1955) mentioned that seed treatment was thought of as early as A.D. 50 by Junius Collumella. Pliny in A.D. 60 described the use of wine and crushed Cypress leaves for this purpose as quoted by Horsfall (1945) and Martin (1959). No further attempts
to treat seed were recorded until 1920 when Becon compared
the treatment of cereal seeds with dung, ashes and soot
or alcohol probably with the objective of controlling
diseases (Ordish, 1977). In 1937, Remnant described a
seed treatment for brown, which may be the earliest record
of the use of brine for this purpose (Horsfall, 1945).
Tillet in 1786 planted experimental plots with untreated
seed or treated with salt and lime, or nitre and lime
which must be regarded as the first scientific seed
treatment experiment (Ordish, 1977).

A number of references regarding seed treatment with
arsenic or corrosive sublimate (mercuric chloride), copper
sulphate and formalin during the early 20th century have
been mentioned by Horsfall (1945), Martin (1959) and
Ordish (1977). The development of organochlorines
transformed the situation and their use as seed treatment
was pioneered in Great Britain, Canada and the U.S.A.
The first use of organochlorine insecticides was introduced
for seed treatment by Jameson et al. (1947). With
increased intensification of cereal growing, the problems
caused by pests and pathogens were exacerbated so that a
greater proportion of seed had to be treated with
insecticides as well as fungicides.

A number of papers are available on insect pests of
cereal crops where insecticidal seed treatments have been
tested by various workers against southern corn rootworm
false wireworm (Daniels, 1955), seed attacking beetle (Starks and Lilly, 1958 b), wheat cury mite (Kantack, 1955; Kantack and Knutson, 1958), Hessian fly (Brown, 1950; Guyer et al., 1955; Wilson et al., 1960), grasshoppers and wheat stem fly (Skoog and Wallace, 1964), cereal leaf beetle larvae (Ruppel, 1969) and curculionid beetles (Allen, 1971).

Narayanan and Rattan Lal (1952) reviewed the chemicals tried by the Department of Agriculture, Punjab during 1925-29 as seed treatment against termites. It appears to be the first attempt of seed treatment tested for the control of termite infesting wheat crop in India. The treatment with mercuric chloride 0.25 per cent or copper sulphate 0.55 per cent was found to be effective as a deterrent against termites and their viability was not affected. The trials conducted by these authors at Delhi for the control of termites (generally Microtermes obesi) attacking wheat crop during 1945-46 did not find significant difference among various treatments due to low infestation. However, during the second year the treatment of wheat seed with pp-DDT 5 per cent emulsion and gamma BHC 0.5 per cent dust were significantly effective in checking the termite attack.

Bindra (1960) conducted trials in Madhya Pradesh by mixing insecticides with the seed for the control of wheat termites (mentioned several species including Microtermes
spp. and *Odontotermes obesus*. Aldrin and dieldrin both gave complete protection against termites. He recommended mixing of aldrin 5 per cent dust with seed just before sowing at the rate of 20-40 lb per acre on the basis of good protection, giving higher yield and being cheaper than dieldrin. In Gujrat, Patel (1962) found seed dressing at the rate of 2 lb of BHC 50 per cent per 112 lb of seed highly effective in reducing termite attack by 86 per cent and increasing grain yield by 55.9 per cent over control in wheat crop.

Rose (1962) reported satisfactory results with dieldrin as a seed dressing at a rate of 1 lb of 50 per cent wettable powder to 240 lb of maize seed. Bigger (1965) in Tanganyika for the control of termites in maize and soya crops found seed dressing of dieldrin 75 per cent at the rate of 0.1 oz per lb seed as excellent and cheaper than soil application of aldrin. The yields raised by 330 to 500 lb in maize and of soya by 110 to 180 lb per acre.

In Haryana, Sahni and Butani (1966) conducted a trial against termites (*Odontotermes obesus* and *Microtermes obesi*) responsible for damage to wheat crop. They obtained good germination and higher yield over the control when wheat seed was treated with aldrin emulsion and BHC suspension. However, the exact dosages used were
not indicated by them but they recommended one litre
a.i. of aldrin per quintal of seed in required quantity
of water.

From Rumania, Balciu et al. (1971) reported seed
dressings and sprays of fungicides and insecticide-
fungicide combination to wheat and barley for the control
of *Zabrus tenebrioides* (Lecoze) and fungal diseases. Mixed
treatments containing gamma BHC and thiram and either
hexachlorobenzene or cupric trichlorophenolate afforded
good protection against this beetle.

Verma et al. (1974) evaluated the effectiveness of
aldrin and BHC with dosages ranging from 0.625 to 1.875
and 1.25 to 2.5 kg a.i. per hectare, respectively, by
various methods for the control of *Microtermes obesi*
in wheat. They obtained lesser tiller damage at
growth and ear-forming stages with higher yield than
control by aldrin seed dressings but treatment by this
method was found to be inferior to pre-sowing soil
treatment and application with irrigation water in
respect of yield. Further field experiments for the
control of *Microtermes obesi* in wheat were conducted under
irrigated and dry farming conditions by Verma et al. (1975).
BHC dust or wettable powder and aldrin as dust or
emulsifiable concentrates were applied to dry or
moistened seeds or soil before sowing. An emulsifiable concentrate of aldrin applied at 125 g toxicant per 100 kg seed proved most effective. Seed treatments with dust of BHC at 125 g and aldrin at 62.5 g per 100 kg seed improved the yield although they were less effective in checking termite attack.

In Punjab, Chahal et al. (1976) found seed dressing of wheat with aldrin 30 e.c. at the rate of 240 ml added to one litre of water for 30 kg seed as highly effective and cheaper than BHC treatment.

Sands (1977) has given the dosages of several insecticides used or recommended by various authors for seed dressing against termites of cereal crops which ranged from 200 to 900 g a.i. per quintal of seed.

Experiments on the effects of treating wheat seed with either BHC 10 per cent or 5 per cent malathion at the rate of 250 and 125 ppm a.i., respectively were carried out by Verma et al. (1979 a) during 1973-75. Significantly less termite damage occurred in plots raised from treated seeds than the controls during the second year although no significant difference was found in the first year. The per cent increase in grain yield over controls were 26.7 and 13.4 for BHC and 19.7 and 29.7 for malathion in 1973-74 and 1974-75, respectively. Trials against termites on rainfed and irrigated barley crop were
conducted by Verma et al. (1979b). Aldrin emulsifiable concentrate and dust and BHC dust was used for seed treatment, and in soil application dusts of aldrin and BHC were taken. Aldrin 30 e.c. at the rate of 10 ml (after diluting with water to make 125 ml emulsion) per kg seed proved to be the best as regards termite control, grain yield and economics of treatment. Aldrin 5 per cent dust at the rate of 10 g per kg seed was also effective.

Post-sowing treatment:

Ayyar (1938) suggested mixing of crude oil emulsion or tar water with irrigation water for the control of Microtermes obesi on wheat in south India.

Srivastava et al. (1962) treated the termite infested wheat crop at the rate of 20 and 25 lb per acre both with aldrin 5 per cent, BHC 5 per cent and heptachlor 6 per cent dusts. Aldrin at the rate of 25 lb per acre gave effective protection, reducing plant mortality from 71.0 per cent in control to 2.9 to 3.5 per cent in treated plots. The treatments with BHC 5 per cent and heptachlor 6 per cent dusts were less effective.

Verma et al. (1974) used three different dosages of aldrin emulsifiable concentrate and BHC wettable powder with first irrigation after 25 days of sowing to wheat crop to check the infestation of Microtermes obesi. They found that all the three dosages of BHC and the lower two
dosages of aldrin did not prove better than control with regard to damage during the growth stage of the crop. However, all the insecticidal treatments proved better than control in reducing crop damage during the ear-formation stage and also in increasing yield. Aldrin at the rate of 1.875 kg a.i. per hectare with irrigation water was found to be one of the best treatments. Presowing soil application and seed dressing treatments were also at par.

Sanchu and Sohi (1977) for the control of two widely distributed species of termites (Microtermes obesi and Odontotermes obesus) infesting wheat crop in Punjab recommended broadcast in standing crop of 50 kg per hectare of sand impregnated with 0.625 to 1.25 litre of aldrin 30 e.c. formulation in 5 litres of water. It was found effective for irrigated and unirrigated crops both. Moreover, all doses of aldrin 30 e.c. formulation from 0.625 to 5.00 litre were also found effective when applied with irrigation water. The control ranged from 85 to 90 per cent. Alternatively, BHC 50 per cent wettable powder used at the rate of 1.25 kg per hectare and other higher dosages proved effective which gave 82 to 90 per cent control.

Mound treatment:
Termites mounds form the foci, wherefrom infestation spreads to the neighbouring fields. Therefore, the
destruction of these mound-building termite colonies is necessary to "nip in the bud". In Rajasthan, the most common mound-building species of termite which infests the agricultural crops is Odontotermes obesus (Rambur).

Several methods and chemicals have been suggested for the control of mound-inhabiting termites. Andrews (1913) reported the testing of fumes liberated from a special compound which were pumped into the mound by a 'Universal' machine for about half an hour. A deposit of sulphur for some distance showed insufficient combustion due to lack of air and thus partial success was achieved in killing the inhabitants.

It has long been believed that if the termite queen is killed, the entire colony is eradicated (Fletcher, 1914; Ayyar, 1938). But such measures often resulted in only a temporary reduction of termite population because the supplementary reproductives had the capacity to re-establish the colony after sometime (Harris, 1961). Therefore, the alternative method of use of chemicals, being more effective was advocated.

Glover (1937) suggested the blowing in of hot poisonous gases over live charcoal in a brazier. Beeson (1941) recommended the removal of above ground parts of the termitaria and inserting of 0.25 to 0.50 oz arsenic
powder mixed with dust through the exposed cavities of each termitarium. He also suggested the blowing in of pure white arsenic powder into a hole made with a crowbar or soil auger from one side towards the centre of the mound. Another recommendation given by him was the use of fumigants like creosote and kerosene or petrol (1:3) mixture, carbon bisulphide or carbon disulphide emulsions or dichlorobenzene liquid or crystal.

Mukerji and Mitra (1948) reported that mound inhabited colonies of Odontotermes redemanni (Hastmann) in west Bengal were successfully exterminated by various organic and inorganic chemicals including kerosene oil (at 1 gal per 14 cubic feet of mound volume), DDT (10 per cent dust at one pound per cubic feet) and BHC, DDT and creosote in various proportions in kerosene oil. The Forest Research Institute, Dehradun (Anonymous, 1949) advocated the use of DDT and BHC for the destruction of termite nests. Pruthi and Singh (1950) recommended the fumigation of mounds by carbon bisulphide and ethylene dichloride etc. Geigy Insecticides (1951) suggested pouring of DDT one per cent suspension to the soaking point over the fungal gardens exposed by breaking open the termitarium.

Roomwal (1951, 1952) recommended pouring in either one per cent DDT or 0.2 per cent BHC emulsion into the holes of the termitarium, by means of a funnel at the
rate of two gallons per ten cubic feet of mound volume. The volume of the mound was calculated by the formula: 
\[ V = \pi r^2 h, \]
where \( V \) is the volume, \( r \) is the radius and \( h \) the height of the mound.

In Malaya, colonies of *Macrotermes gilvus* were effectively killed by treatment with 0.64 per cent aldrin emulsion or 0.036 per cent dieldrin emulsion, the former taking a week and the latter 10 days to achieve complete kills (Anonymous, 1954).

Singh and Sharma (1957) proposed a formula for the calculation of mound volume to determine the quantity of liquid required for drenching. They compared various dosages of DDT, BHC and aldrin for the destruction of nests of *Odontotermes gurdaspurensis* Holmgren and Holmgren. Consistently effective results with aldrin emulsion were obtained for the destruction of termite colonies and even 0.0041 per cent concentration was found enough for the purpose. BHC 0.1 per cent suspension, though effective was not dependable and DDT was partially successful.

For calculating the dosages of liquid insecticide required for effective control of subcylindrical mounds of *Odontotermes obesus*, Roonwal (1958), proposed a height-dosage relationship table. The quantities of liquid worked out ranged from one gallon to twenty seven gallons for the heights ranging from three to seven feet, respectively.
Bindra (1960) obtained complete control of certain mound-building termites (*Odontotermes* spp., including *O. obesus*) by applying 2 oz of any of the following insecticides per nest; DDT, BHC as 50 per cent wettable powders and emulsifiable concentrates of chlordane 75 per cent, toxaphene 25 per cent, dieldrin 18 per cent, and aldrin 40 per cent at the rate of one oz per nest. The insecticides were dissolved in 10 gallons of water to pour into the termitaria.

Roonwal and Chatterjee (1960) conducted a series of experiments during 1951 and 1956 for the extermination of colonies of mound-building termite *Odontotermes obesus* (Hambur). Aldrin, dieldrin, BHC and DDT were used with different concentrations in 500 to 9000 ml of liquids per 10 cubic feet of mound volume. They concluded that the use of chlorinated hydrocarbons was effective and cheaper in destroying the entire colony in less than a week's time. The cost of insecticide including labour and water per 10 cubic feet of mound at the 1960 price levels was calculated as 18, 20, 21 and 26 paisa for 0.005 per cent gamma BHC, 0.04 per cent DDT, 0.025 per cent aldrin and 0.025 per cent dieldrin, respectively. They also stressed that both concentration of the insecticide and the total quantity of the liquid poured into the mound are important in ensuring adequate destruction.
Deoras (1962) tested the dusts, suspensions and emulsions of some insecticides which were applied by breaking open the towers of mounds, inhabited by Odontotermes spp. The use of DDT and BHC five per cent dust at the rate of 2 oz was unsuccessful as the termite workers had either sealed off the treated area or covered it with earthen galleries to avoid contact with the insecticide. Suspensions of two per cent BHC and DDT, and emulsion of two per cent pyrethrum applied at the rate of one gallon were absolutely successful but two per cent crude oil emulsion was ineffective.

Sands (1962) achieved successful control of Macrotermes natalensis which constructs large mounds in northern Nigeria with 2.5 fluid ounces of aldrin 4C per cent emulsifiable concentrate in six gallons of water applied through auger holes made into the central hive containing the queen cell and associated chambers. A possibility of further reduction in insecticide dosage was also hinted by him.

Roorwal and Guha-Roy (1964) for the Odontotermes obesus type of mounds found that a non-linear equation (a quadratic curve) fits better than a linear one to calculate the volumes of different mound heights e.g. height 1 cm, 2,000 ml; 10 cm, 10,750,000 ml; 20 cm, 82,80,000 ml.
Fumigation of mounds with aluminium phosphide (Phostoxin) gave promising results in India as mentioned by Sands (1973), but Bastos et al. (1971) reported failure of doses of one to four pellets per mound to control *Coptotermes curculionis*.

Recently, experiments were carried out by Rajagopal and Veeresh (1978) on the mound poisoning of *Odontotermes wallonensis* (Wasmann). The size of the mounds varied from 1 to 5 metre in diameter and 25 to 100 cm in height. Aluminium phosphide at 9 g, phorate 10 per cent granules at 50 g, chlordane 20 per cent emulsifiable concentrate at 50 ml and chlorpyrifos 20 per cent emulsifiable concentrate at 20 ml per mound, completely destroyed the termites including some associated animals inside the mound, if any. Ethylene dibromide at 3 ml and BHC 50 per cent wettable powder per mound were less effective and gave only 50 per cent and 25 per cent control, respectively.