DISCUSSION
Adherence of pesticidal powders

Relative adherence of dry powders:

The tests of adherence with dry pesticidal powders to wheat and barley seeds revealed a great variability in the amount of coatings in the present studies. Maximum amount of 1.382 and 1.474 kg of chlordane dust and a minimum quantity of 0.289 and 0.319 kg of lindrin wettable powder was retained on wheat and barley seeds, respectively, when the pesticides were applied at the rate of 2 kg dry per 10 kg seed. Other pesticides showed different amounts of adherence. The grouping of wettable powders of different pesticides, dust and wettable formulations of the same pesticide and even the two differing dust percentages of a pesticide did not signify any similitude in the amount of retention. Such variations in the deposition of pesticides as emphasized by Ebeling (1963) are due to the involvement of a number of factors like size, shape, electrostatic charge of the particles, the chemical and physical properties of the diluent, adjuvants etc. and the nature of the adhering surface. While determining the adherence of several pesticides on wheat, Baicu and Diaconu (1972) found that only compounds, PEL-120, PLB and TaZ gave the best adhesiveness. Decker et al. (1950) observed that pesticides like chlordane
and toxaphene which leave waxy or sticky deposits adhered better than those that leave crystalline deposits like DDT. Metcalf and Flint (1962) have also mentioned that oily materials help in increasing the deposits. The findings of all these authors adequately conform to the present investigations where a great variability in adherence has been noticed and chlordane showed the maximum deposit on wheat and barley seeds.

It was further observed that barley seed retained comparatively more quantum of powder than wheat seed. Băicu and Diaconu (1972) reported that the adhesiveness on the seed is basically related to its size as smaller seeds retained larger amounts. Although barley seed used in the present studies was slightly bigger in size than wheat seed, still it retained a higher amount of powders. Jeffs and Tuppen (1978) indicated that adhesion of particles is a complicated process involving factors from molecular forces to physical trapping of small particles. Hence, it is conjectured that the rough and pubescent surface of barley seed provided favourable chances for physical trapping of particles leading to more deposits. Relatively lesser deposits on wheat seed inspite of its smaller size would have, therefore, occurred due to its smooth surface.
The application of different powders at the rate of 2 kg dry per 100 kg seed showed the practical adherence ranging from 9.45 to 69.10 per cent for wheat and from 10.98 to 73.70 per cent for barley (Table 3). Lord et al. (1971 a,b) also observed that dry powders become separated from the seed as they do not adhere strongly to the seed. The commercially treated seed samples examined by these workers revealed adherence even less than one-tenth of the theoretical dose applied in some cases. It is thus seen that with the dry application of pesticidal powders, a lesser amount retains on the seed than the actual dose of application. Moreover, the type of formulation and the kind of seed are also responsible for the variability in the quantum of pesticidal loading.

Effect of various dosages on adherence:

The investigations of Drivastava (1965) indicated a significant increase in the coating on wheat seed as the concentrations of pesticidal powders were gradually increased from 2 to 32 oz per 100 lb seed. He found that the rate of increase was not uniform for all the treatments. Only slight increase in adherence was observed by him in neptecilol between 16 and 32 oz concentrations whereas 'Seed Guard' gave the highest coating. The present observations also revealed significant increase in the
coating of the three pesticides tested here on wheat and barley seeds. For example, on wheat seed the loadings of chlordane 5 per cent dust were 0.833, 1.389 and 1.923 kg per 100 kg seed with the application of 1, 2 and 4 kg dosages, respectively (Table 4). However, the rate of increase did not follow a linear pattern beyond 2 kg rate. It is seen that in wheat the additional loading of chlordane was 0.550 kg with the rise of application rate from 1 to 2 kg, and 0.145 kg with the rise in application rate from 2 to 4 kg. Chlordane 5 per cent dust gave the highest coating on wheat as well as on barley seeds followed in decreasing order by aldrin 5 per cent dust and BHC 10 per cent dust at various dosages. Thus these results in general corroborate with the findings of Srivastava (1955).

Determination of a suitable sticker:

The application of dry powder does not provide a desirable amount of loading on the seed to achieve necessary protection to the germinating seed or plant from the invading pest. Several materials have been mentioned in the literature as stickers to increase adherence. Generally, 2.5 to 3 per cent methyl cellulose is used as a sticker (Reynolds, 1955). From an economical viewpoint, aside methyl cellulose, gum arabic and soluble starch were also tested here. The results of
the present studies demonstrated that 2 per cent methyl cellulose was the best adhesive in comparison to gum arabic and soluble starch at the same concentration (Table 6). It was also observed that irrespective of the dry adherence ability of a pesticide, the stickers brought about a uniform amount of loading at lower dosage and methyl cellulose even at higher dosage demonstrated the same trend due to its strong force of adhesion. It was also seen that the adherence of powders increased with the rise of application rate. The use of stickers for uniform and better coating has been advocated by Starks and Lilly (1955 b). Similarly, Jeffs (1973) and Jeffs and Walker (1973) obtained more quantity of pesticidal powders on the seed with the use of sticker. Griffiths et al. (1976 a) in their test confirmed that certain adhesives allowed better loading on the seed in comparison to standard siliceous earth formulations. The present data are thus in agreement with the findings of these researchers.

Effect on germination

Usually a compound in soil application may not be so harmful to germination than when used with the seed because the latter method of treatment places the chemical in an intimate contact with the seed. Detrimental effect on germination caused by seed treatment with certain
chemicals are well known and the severity of such effects is mainly due to the nature of the chemical. Over and above, the degree of its influence is also dependent upon the applied dosage, the type of formulation, the technique of treatment, the kind and variety of seed, as well as other conditions of experimentation.

The results of the present studies on seed treatment of wheat and barley reveal that several factors are responsible for the extent of influence on germination. They are the specificity of the pesticide, the dosage loaded on the seed, the type of formulation, the kind of seed and the testing conditions.

Specificity of pesticides:

The specific effects of certain compounds on germination by treating wheat and barley seed were observed under green-house and field tests (Tables 7 to 10 and 23 to 26). The dry application of dusts not exceeding 10 per cent, a 40 per cent isophenphos + TMTD s.d. and 75 per cent larvin w.p. did not hamper the germination of wheat in green-house test. However, 50 per cent w.p. of CBG, carbaryl and landrin were found to be injurious to germination of wheat. Obviously one of the possible reasons of the adverse effects on germination by these wettable formulations was their
more concentrated form in comparison to most of the other compounds tested along with them. On the other hand it was also seen that larvin w.p. which was in a highly concentrated form than the rest of the wettable powders, did not affect adversely on the germination. From the results it appear that the two new compounds, landrin and larvin w.p. of the carbamate group behaved unlike each other in respect of germination. Similarly, another recent combination product, isophenphos + TMTD 4C per cent s.d. loaded on the seed in comparable amounts to 50 per cent w.p. of BHC and carbaryl (Tables 1) did not hamper germination (Tables 7 and 23). It was further observed that aldrin 5 per cent dust was quite suitable when applied at 2 and 4 kg rates with sticker to 100 kg seed of wheat. Whereas, 5 per cent BHC, chlordane and heptachlor dusts with approximately the same amounts of loading on the seed at both these rates inhibited the germination. These findings indicate that pesticides at the same rate of application may behave differently in the degree of their effectiveness mainly due to their specific chemical composition. The treatment of barley seed with wettable powders of BHC, carbaryl and landrin also affected the germination while larvin did not.

The data on seed treatment of wheat with emulsifiable concentrates at the lowest dosage with chlordane, chlorpyriphos, lindane, phenthoate and phoxim pesticides
indicated significantly lesser germination than control. At the same rate of application the treatment of aldrin, endosulfan, heptachlor, isophenochos and malathion + DDT + BHC gave as good germination as untreated check. The barley seed treated with emulsifiable concentrates also demonstrated that a few pesticides with a similar dosages were unfavourable to germination while others did not hamper the germination.

The germination recorded in the microplot tests of wheat and barley treated with powder and emulsifiable formulations showed a similar trend of diverse effects of certain compounds.

It is thus quite clear from these results on germination that certain pesticides impaired germination while others either caused no adverse effect or just affected mildly, albeit the dosage was the same. These results have also elucidated an additional information that some recent pesticides i.e. lamdin, phenthoate and phoxim retarded the germination of wheat and barley.

Several workers (Fleming, 1948; Primost, 1950; Jameson et al., 1951; Cox and Lilly, 1952; Srivastava, 1955; Patel, 1962; Bowling, 1964, 1965; Sahni and Butani, 1966; Sachan et al., 1967; Griffiths et al., 1969; Verma et al., 1979 a,b) have observed the effects of some common
and a few new pesticides on germination of cereal crops. Their results can not be compared directly with the present results obtained for these pesticides. It is because of the deviation in the technique of treatments, the pesticides, their formulations and the dosages used as well as the methods of testing adopted by various workers. However, the effect of seed dressing on germination of wheat with dust formulation of aldrin, BHC, chlordane and lindane with similar dosages was compared by Bindra (1956). He found that except aldrin, all the other compounds gave relatively poor germination indicating the specificity of these chemicals. The influence of the nature of BHC is further evident from the data of Verma et al. (1971). They found that wettable powder of BHC used as dry or wet was injurious to germination of wheat. In a subsequent study Verma (1974) observed that aldrin dust did not inhibit wheat germination while BHC dust adversely affected the germination when the seed was treated with equal amounts of the pesticides. Allen (1971) treated wheat seed with identical dosages of phosalone and endosulfan and found that the former treatment reduced the germination while the latter caused no inhibition.

In this way, broadly speaking the present findings extent support to prior observations of other workers with regard to specific effects of pesticides on
germination when used as seed dressers.

Effect of dosages:

Besides, the specificness of the compound for its effect on germination, the degree of inhibition is also influenced by the amount of the pesticide retained on the seed. The results dealt in these studies have displayed the trend of declining germination on account of the increasing rate of application with most of the compounds.

The treatment of wheat seed with dry wettable powders of BHC, carbaryl and lindane at the rate of 2 kg per 100 kg seed demonstrated adverse effects on germination in comparison to other compounds in green-house tests (Table 7). The germination further declined due to increased loading when these pesticides were applied at 2 and 4 kg rates with sticker. For example, BHC wettable powder treatment at 2 kg dry gave 75.1 per cent germination and the application of 2 and 4 kg with sticker allowed 46.0 and 10.8 per cent germination, respectively. The dry application of BHC 5 and 10 per cent dusts at 2 kg was not harmful to germination but these compounds manifested reduction with the increase in pesticidal loadings. The application rate of 2 and 4 kg dust with sticker retarded germination from 90.5 to 73.2 per cent in BHC 5 per cent and from 84.4 to 45.0 per cent
in BHC 10 per cent dust, respectively. Even certain pesticides like aldrin, endosulfan and larin powders which did not cause a significant reduction in germination with increased coating indicated a non-significant numerical decrease. The germination of barley seed treated with powders also evidenced the increasing inhibition in germination with the rise of adherence in green-house test (Table 8). For instance, BHC w.w. showed 99.7, 94.2 and 84.4 per cent and lendarin w.o. gave 100.0, 91.0 and 83.1 per cent germination, respectively, at the rate of 2 kg dry, and 2 and 4 kg with sticker. The microplot trials of wheat and barley seed treated with powder formulations exhibited the same tendency of decreasing germination with increasing amount of pesticidal coating on the seed (Tables 23 and 24).

Treatment of wheat and barley seeds with emulsifiable concentrates have shown that the germination declined gradually with the increasing rate of application in green-house as well as in microplot tests. The effect on germination with emulsifiable formulations of chlorpyriphos, lindane, phenthoate and phoxin treatments was more severe than other compounds like aldrin, endosulfan, isophenphos and malathion + DDT + BHC.
wheat and barley seeds treated with powder and emulsifiable formulations and tested under green-house and field conditions indicate the existence of a positive correlation between the dosage and the germination. Supporting evidence in this context is available from the investigations of previous workers despite several deviations in their methods of experimentation. Srivastava (1955) treated wheat seed with a variety of pesticidal formulations at various dosages. His findings revealed an increasing decline of germination with a few proprietary formulations containing lindane. The compound Panogen, PL-1 gave 83, 79 and 44 per cent germination at the application rate of 2, 2.5 and 3.5 oz per 100 lb of seed, respectively. Bindra (1960) used certain pesticides for seed dressing of wheat at the rate of 20 and 40 lb per acre. He mentioned that BHC and chlordane 5 per cent dusts especially at the higher rate affected germination, although no figures were given by him. Further evidence to the decline of germination was explored by Patel (1962). He treated wheat seed with BHC 50 per cent w.p. at the rate of 1, 2 and 4 lb per 112 lb of seed. The mean number of plants germinated per plot were found to be 1444, 1008 and 608 with the application rates of 1, 2 and 4 lb, respectively. Allen (1971) observed that some pesticides suitable at a lower rate for seed treatment of wheat, retarded germination at the higher rate. The investigations
of Verma et al. (1971) on the seed treatment of wheat revealed reducing germination due to the increasing dosages of pesticides. Application of BHC 50 per cent w.p. as dry at the rates ranging from 0.125 to 0.625 kg a.i. per 100 kg seed gave germination varying from 54.8 to 26.4 per cent. Same dosages of this pesticide applied to moistened seed depicted variation in germination from 45.5 to 8.5 per cent. Treatment by aldrin emulsion with dosages ranging from 0.250 to 1.075 kg a.i. allowed germination ranging from 47.8 to 15.3 per cent. The influence of various concentrations of menazon, disulfoton and G6-14254 pesticides on germination of wheat by seed treatment was studied by Dalvi et al. (1972). They found that the degree of inhibition of germination depended on the concentration of the chemical. Another study by Verma (1974) on the seed dressing of wheat with dust formulations of BHC and aldrin indicated a decline in germination with the increasing dosages of BHC. Further evidence in this direction with respect to barley seed treatment with various dosages of aldrin is available from the data of Verma et al. (1979 b).

From the foregoing discussion it is quite clear that the present observations substantiate the results of earlier workers in-as-much as the differential effects of concentrations of various compounds on germination are concerned.
Effect of formulations:

A pesticide may be applied to the seed in various forms. Different formulations have limitations and advantages with respect to their use for seed treatment. Some potentially phytotoxic insecticides can be applied in powder form without any damage to the seed while a liquid form usually damages the seed (Jeffs and Tuppen, 1978).

The laboratory test with seed treatment on rice by Holston et al. (1960) revealed that the application rate of 4 oz per bushel with aldrin emulsion reduced the germination but aldrin w.p. at the same dosage did not effect the germination. Bowling (1964) used 50 and 75 per cent w.p. and a liquid formulation of aldrin each with 4 and 8 oz a.i. per 100 kg seed for the treatment of seed rice. The liquid formulation of aldrin at both the rates caused greater reduction in germination and emergence as compared to wettable powders tested at the same rate. For example, at the dosage of 8 oz the mean total germination in 75 and 50 per cent w.p. and liquid aldrin, was 86.2, 86.5 and 86.1 per cent, respectively. Similarly, at the same dosage the total emergence was 20.6, 20.3, and 17.4 per cent with 75 and 50 per cent w.p. and liquid aldrin, respectively. Another study by Bowling (1965) on seed rice dressings with various formulations indicated that the emergence was lower in aldrin
and endosulfan liquid treatments than the same insecticide used as wettable powders.

The application of powders in the present studies was not based on measured amounts of active toxicant as adopted for emulsifiable concentrate treatments. Nevertheless, a few commercially formulated dosages of some pesticidal powders loaded on the seed coincided approximately with the amounts of active toxicants carried by the coatings of emulsifiable concentrates, thus making a comparison possible (Tables 1 and 2). The application of 4 kg chlordane dust with sticker loaded 190.26 g a.i. on wheat seed, gave 83.0 and 74.0 per cent germination in greenhouse and microplot tests, respectively. On the other side, the dosage of 200 g a.i. of emulsifiable formulation gave 58.0 and 52.0 per cent germination in greenhouse and microplot tests respectively. Similarly the application of heptachlor dust at the rate of 4 kg with sticker coated 193.82 g a.i. on wheat seed gave 86.1 and 78.7 per cent germination in greenhouse and field tests, respectively. Whereas the dosage of 200 g a.i. of emulsifiable formulation of heptachlor allowed 68.0 and 52.7 per cent germination. These differences in germination with different formulations of one pesticide under both the conditions of testing are quite discernible and can be safely attributed to the formulation effect. It may be due to the fact that seed to seed distribution is fairly
uniform in the application of dusts but in liquid application, formulation of large drops and their adherence on or near the sensitive region of the seed would be damaging to the embryo as evidenced by Jeffs and Griffiths (1975). These authors have argued that cereal seeds are damaged by solutions of phytotoxic substances due to penetration into the seed via scutellum. While the powder formulations of potentially phytotoxic insecticides composed of mixture of active ingredient and inert powder do not penetrate the seed coat in phytotoxic concentrations to cause damage to the seed. Thus the present data support the documentation of the earlier workers that liquid formulations are relatively more toxic than the powder formulations at identical rates of application. However, aldrin and endosulfan which are least phytotoxic to germination did not demonstrate any appreciable difference with comparable dosages on account of formulation in the present findings.

Effect of seed type:

Seed tolerance of various crops to a chemical varies and differences even within the varieties do exist (Brooks and Anderson, 1947; James and Anderson, 1947; Cullinan, 1949; Lange et al., 1949; Srivastava, 1955; Lange, 1959). Barley, rye, wheat and oat seeds were treated with two different dosages of DDT dust by Primost (1956). His results indicated that at higher
dosage the adverse effect on germination was negligible in case of barley as compared to other crops. The investigations of Cox and Lilly (192) with several field crops also demonstrated that barley was more tolerant than wheat, and crops of sorghum groups were the most susceptible.

In the present, greenhouse tests on germination of wheat with dry application of powders at a rate of 2 kg per 100 kg seed revealed adverse effects of wettable powders of BHC, carbaryl and lanolin treatments (Table 7). The same rate of application with these pesticides in barley did not reflect any harmful effect on germination (Table 6). Further, the treatments of BHC 5 and 10 percent dusts, BHC, carbaryl and lanolin wettable powders, heptachlor, chlordane and malathion + DDT + BHC dusts and isophentophos + TMTB s.d. when applied at the rate of 4 kg with sticker to wheat seed reduced germination. In case of barley with the same dosage only wettable powders of BHC, carbaryl and lanolin affected the germination while the other pesticides did not impair. Additional evidence in this context is available from the data of emulsifiable concentrate treatments given to wheat and barley seeds. Chlordane, chlorpyrifos, lindane, phenthion and phoxim at the rate of 80 g a.i. demonstrated unfavourable effects on the germination of wheat (Table 9), whereas
only lindane affected adversely on the germination of barley (Table 10). With the application of 200 g a.i. dosage to wheat seed, it was noticed that all the pesticides except malathion + DDT + BHC inhibited the germination. While in barley aldrin, endosulfan and isopropophos besides, malathion + DDT + BHC treatment did not retard the germination. Similar behaviour of the pesticides on germination was seen in the microplot tests.

Thus the above discussion is ample to draw a corollary that certain pesticides harmful to the germination of wheat at effective dosages are innocuous to barley. The reason of varied susceptibility of wheat and barley seeds may be conveniently attributed to their seed coat, shape, size and structure. Lange (1959) has also mentioned that seed factors play an important part in determining the seed vitality against various pesticidal treatments. Hence, the present results corroborate with the reports of earlier workers.

**Effect of testing conditions on germination:**

The comparison of germination data obtained under green-house and microplot tests (Tables 7 to 10 and 23 to 26) indicate that the inhibition of germination was more pronounced under microplot field conditions than in the green-house tests. Further examination of soil type, soil moisture, organic matter contents of the soil and the depth of seed placement revealed that except the soil
type all the other factors were varied. In microplot field tests the sowing was done at 90 per cent available soil moisture which depleted to nearly 50 per cent during the period of germination. On the other hand, in the greenhouse tests by frequent watering of pots the moisture was maintained very close to field capacity (100 per cent available soil moisture). As such the moisture level was less in the field tests as compared to greenhouse tests. The microplot soil had slightly more organic matter (0.13 per cent organic carbon) than the soil used in greenhouse (0.11 per cent organic carbon). Moreover, in the microplot tests the seed was placed at a depth of about 5 cm while in the greenhouse test the seedling depth was about 1.5 cm.

Lange (1959) in a review article on seed treatment as a method of control has projected that besides several other factors, soil characteristics and planting practices also enter into the value obtained from seed treatment. Harris (1972) after a critical review of the reports on the factors influencing the effectiveness of soil insecticides concluded that soil type, soil moisture and organic matter content greatly affect the biological activity of the insecticide. In soil, the insecticide is adsorbed on the clay or organic matter of the soil and competes with water for adsorption site. The biological activity of the insecticide is more in lighter soils than
heavier soils and is adversely affected with increase in organic matter content of the soil.

In the present studies the soil type was the same under green-house and a microplot field experiments but the organic matter content of microplot soil was slightly higher with relatively less moisture content as compared to the soil of green-house tests. The variation in the organic matter content is so less to have any significant effect on germination. Thus the observed differences in seed germination under the two sets of conditions may well be attributed mainly to variation in soil moisture levels. As exemplified by Harris (1972) the bioactivity of soil applied insecticides is positively correlated with the soil moisture content, whereas in the present green-house studies the soil moisture content was more, the germination was also more showing less inhibitory effect of insecticide on germination. It is, therefore, probable that the soil moisture influences both the bioefficacy of insecticide after incorporation in the soil and the inhibitory effect of insecticide on germination following seed treatment. In the former case, soil moisture increases the toxicity of the insecticide applied into soil but in the latter case, the moisture enhances the process of germination and thereby reduces the phytotoxic effect of the insecticide to the germinating seed. Kirk
and Wilson (1967) also observed that following seed treatment of wheat with insecticides, the germination was maximum when adequate soil moisture was maintained by regular watering the pots but the germination was impaired when soil moisture was only slightly above the wilting point. Excess of soil moisture also adversely affected the germination. In addition to soil moisture, the depth at which the seed is placed in the soil also plays an important role in germination. In the microplot tests the per cent germination was less even in the control as the seeds were placed at a deeper level than the seedling depth in the green-house tests.

Phytotoxicity symptoms in wheat and barley seedlings:

Phytotoxicity induced by crude BHC or lindane treatment has frequently been quoted for certain cereals including wheat and barley. The symptoms described by different workers are malformation of plants, atypical growth, shortened and thickened plumule, polyploidy and swelling of root tips, absence of root hairs, necrosis on the rootlets etc. (Kostoff, 1948, 1949; Hocking, 1949; 1950; Jameson and Callan, 1951; Ozkan and Finci, 1974; Zeller and Hauser, 1974). Slight variations in these descriptions of symptoms are probably due to the dosages and the variety of seed used. The observations recorded in these studies on the phytotoxic symptoms of non-emerging
seedlings caused by the effective pesticides like BHC and lindane have exhibited resemblance as reported by other workers.

The investigations of Cox and Lilly (1962) have indicated the angular emergence of seedlings from the soil surface and also chlorosis in wheat and barley with the application of higher dosages of aldrin in soil. Subsequent to seed treatment of wheat and barley with emulsifiable concentrates of chlorpyrifos and phoxim as well as with BHC wettable powder treatment, angular emergence of seedlings was noticed in the present findings, though the frequency of occurrence was at a low ebb in barley. As regards the symptom of chlorosis, the dosage of 4 kg wettable powder with sticker of BHC, carbaryl and lindane induced chlorotic streaks or patches in the seedling leaves. Indication of damage to young seedlings by seed dressing of wheat with chlorpyrifos and phoxim is available from the report of Griffiths et al. (1969) and agrees with the observation of the present author. However, these authors have not described the symptoms in detail.

From the above narration it appears that the previous workers have described the phytotoxic symptoms appearing in cereals seedlings caused by BHC or lindane only in
some detail. Otherwise only causal or general remark of the phytotoxicity induced by a few other pesticides has been mentioned by other workers.

In the present work, however, phytotoxic symptoms caused by the seed treatment of chlorpyrifos, phenthoate and phoxim (emulsifiable concentrates) and BHC, carbaryl and landrin wettable powders have been illustrated in a categorized manner. To the knowledge of the author, no such detailed and classified symptoms of these pesticides appear to have been explicated by any worker.

**Effect on mean emergence period**

The mean emergence period exhibits the measured mean time required for the emergence of all seedlings for the treatment. Such a figure is a useful unit to compare the over-all effectiveness of one pesticide from the other. This factor is influenced by the seed, the depth of placement, moisture, temperature and the treatment. In the green-house tests of these studies all the factors were maintained uniform as far as possible except the differences of treatments. Thus the variations in the mean emergence periods were directly affected by the characteristic of the compound and its applied dosage.

Seed treatment of wheat and barley with powder and emulsifiable formulations in the green-house tests revealed variations in the mean emergence period. The present
findings in brevity, indicated that certain most effective pesticides at lower dosages delayed the emergence, some were moderately effective and so increased the emergence period with the rise of the dosage, and a few even at the highest tested dosages either caused no delay or affected only mildly. Among the powder treatment, BHC, carbaryl, and landrin wettable powders were mainly responsible for remarkable delay in germination of wheat and barley. Out of the several emulsifiable concentrates tested here, chlorpyrifos, lindane, phenthoate and phoxim treatments caused more delay than the rest of the compounds in both the crops.

The investigations of Lange et al. (1949) on the seed treatment of Fordhook bush bean with lindane demonstrated that mean emergence period increased from 9.91 to 10.27 days with 0.66 and 1.63 oz a.i. dosage per 100 lb seed, respectively, while the untreated seed emerged in 9.26 days. Further evidence to the delay in the mean emergence period of soybeans treated with different pesticides is available from the work of Starks and Lilly (1955 a). All the treatments significantly delayed the emergence in comparison to control. However, relatively less delay but not significantly different from other treatments was observed in aldrin, dieudrin, ortho HL-609 and Benzalax treatments. Lindane
was one of the treatments which comparatively caused more
delay along with a few other pesticides. Another study
by Srivastava (1955) with the seed treatment of wheat
indicated that among the various pesticides, Panogen,
PL-1 (containing 36.6 per cent lindane) caused maximum
delay in emergence. The dosage of 2.0, 2.5 and 3.5 oz
per 100 lb seed of this pesticide brought about a
noticeable delay, showing 7.62, 7.39 and 7.36 mean
emergence days, respectively, in comparison to 5.36
days in control. Aldrin, heptachlor and lindane wettable
powders and a few other pesticides at any of the tested
dosages did not cause pronounced delay in emergence.

From the present data it appears that aldrin,
endosulfan and lindane dusts for wheat, and aldrin, BHC
5 per cent, lindane and endosulfan dusts for barley were
not unfavourable in respect of mean emergence period
even at the highest dosage applied to the seed. The
lindane dust being of a very low concentration induced
no effect. As regards the emulsifiable treatments on
wheat the dosage of 160 g a.i. of aldrin, isoprophos,
endosulfan and malathion + DDT + BHC was not adverse to
emergence and in case of barley, aldrin applied even at
200 g a.i. produced no conspicuous effect on emergence.
Lindane at a dosage of 80 g a.i. for wheat and at 120 g
a.i. for barley was harmful out of all the treatments
applied at similar dosages. Hence, it is inferred that
delayed emergence as observed by earlier workers tallies
with the present data but the extent of delay is related
to the characteristics of the compound, its dosage and
the nature of seed.

**Effect on plant growth**

Top height:

Top height of the seedling is one of the documented
parameters of plant growth to assess the influence of a
pesticide. Cullinan (1949) reported the effects on the
growth of tomato, cucurbits, corn, potato and peas seedlings when grown in soil treated with DDT, BHC, chlordane
and toxaphene. He observed that the lower dosage of 25 lb
per acre depressed the growth of some seedlings. The
growth was even more depressed with the use of higher
centration of pesticide in the soil, particularly of
BHC and chlordane. The findings of Sachan et al. (1967)
indicated that the height of wheat plants was significantly
curtailed by chlordane dust, whereas aldrin, BHC and
dieldrin had no effect. These workers applied the
different dosages of insecticide in shallow furrows, placed
the seed and then covered with soil.

The top height of wheat and barley seedlings
recorded in green-house tests in the present studies
demonstrated varied growths due to seed treatment with powder and emulsifiable formulations. Some of the pesticides used in these studies are common to those used by other workers (Cullinan, 1949; Sachan et al., 1967). Since, either the crop or seedling growth parameters chosen and the conditions of experimentation of these workers were not identical with this author, only a generalized comparison is possible.

As far as the adverse effects of BHC, chlordane and lindane on plant growth are concerned these results agree with the reports of Cullinan (1949). Sachan et al. (1967) have also noted retarding effect on the growth of wheat plants by chlordane dust. All these workers found that the degree of growth suppression increased with the rise of the pesticidal dosages. Similar effects were observed by this author with the seed treatment of BHC and chlordane dusts and lindane and chlordane emulsifiable formulations. However, lindane dust did not reflect such affect due to the very low concentration of the commercial formulation used here. The results of Sachan et al. (1967) are contrary to both, the present observations and to the findings of Cullinan (1949) as regards the effect of BHC dust on plant growth. This bizarreness in the results of Sachan et al. (1967) is a deviation from the normal trend because even the highest
dosage of 30 lb a.i. per acre used by them was not found harmful to the growth of wheat plants. Hence, it is very difficult to interpret the different behaviour of BHC in their trial.

Dry seedling weight:

Seedling weight is another important parameter of plant growth to comprehend the effect of a pesticide (Lange et al., 1949; Cox and Lilly, 1952; Starks and Lilly, 1955 a; Srivastava, 1955).

Studies on seed treatment of two varieties of lima beans with lindane applied at the dosages of 0.66 and 1.33 oz a.i. per 100 lb seed were conducted by Lange et al. (1949). Their results revealed that the average seedling weights recorded with or without cotyledons from both the treatments were significantly inferior to untreated seedling weights in one of the varieties. It was further noted by them that the average seedling weight was significantly reduced at the higher dosage as compared with the lower dosage in both the varieties.

Cox and Lilly (1952) determined the average green weight of wheat and barley seedlings sown in sand treated with 2 to 128 lb a.i. of aldrin and dieldrin per acre. They observed that aldrin and dieldrin suppressed growth with each increase in the application level except a minor deviation from this trend at certain stages of pesticidal
levels. However, the effects of dieldrin were slight in comparison to aldrin. Five soybean varieties were treated with an excessive dosage of 4 oz a.i. of Dic (containing 75 per cent gamma isomer content) per bushel seed by Starks and Lilly (1955 a). They observed that the reductions in average seedling weights of all the five varieties were of little practical importance. Srivastava (1955) worked out the ratios of top to root on dry weight basis for wheat seedlings germinated in flats out of doors following seed treatment with different formulations of pesticides. He found that a formulation Panogen, PL-1 (with 36.6 per cent lindane) applied at the rate of 2.0, 2.5 and 3.5 oz per 100 lb of seed gave root-top ratios as 94.0, 88.0 and 69.0, respectively, which were significantly lower than all the treatments with median and highest dosages each significantly lower. Other treatments each with different dosages of aldrin, lindane, heptachlor and 'Seed Guard' were not significantly different in the mean proportional development of roots compared to tops.

The data reported here with regard to the plant growth takes into account the mean dry weight of the seedling. This was considered more appropriate and precise as compared to green weight which is subject to a great variation in view of the different levels of
wetness retained on the plants when they are processed through blotter after washing to remove the excess moisture.

The dry weights of wheat and barley seedlings observed in the greenhouse tests during these studies revealed variations due to seed treatment with powder and emulsifiable formulations (Tables 19 to 22). The apparent reason for such difference is the type of the insecticide and the applied dosage. The increase in the dosage of an effective pesticide enhances the reduction by dry seedling weight. These data further elucidate that a certain pesticidal dosage effective in reducing the weight of wheat seedling is not adverse to barley. For instance, BHC 5 per cent, chlordane, heptachlor, isophenphos + TATD and malathion + DDT + BHC powders at the dosage of 4 kg with sticker adversely affected the weight of wheat seedlings but not of barley seedlings. Similarly, an emulsifiable concentrate treatment of malathion + DDT + BHC at a dosage of 160 g a.i. adversely affected the weight of wheat seedling while this compound was not unfavourable to barley even at the dosage of 200 g a.i. Thus it is clear that barley seed has a greater tolerance against pesticides than the wheat seed.
A superimposition of the data of both the parameters of plant growth (top height and seedling dry weight) illustrate an interesting feature that certain pesticidal treatments not adverse to top height reflected their adverse effect on dry seedling weight (Tables 15, 17, 18 and 19, 21, 22). This trend is exemplified in wheat with the seed treatment of BHC 10 per cent and chlordane dusts as 2 kg dry, malathion + DDT + BHC dust as 2 kg with sticker and emulsifiable concentrates of isophenphos and malathion + DDT + BHC applied at the rate of 160 g a.i., and in barley with chlordane and chlorpyrifos treatments applied at the rate of 120 g a.i. Contrary to these results in barley the seed treatment with emulsifiable concentrate of phoxim at the rate of 120 g a.i. and endosulfan at the rate of 200 g a.i. adversely affected the top height but not the seedling dry weight. However, the discrepancy of reduced top height but no effect on the dry seedling weight depicted by phoxim and endosulfan treatments might have occurred by compensatory growth in other dimensions of the plants and as such dry seedling weight was not affected while the top height was found to be affected. Keeping in view this argument and the data, the dry seedling weight appears to be a more sensitive and reliable parameter to derive the initial effects of pesticides on plant growth as it takes into account the whole plant instead of a part of it.
From the preceding description it is evident that the methods of treatment, insecticides and their dosages used, the growth parameters chosen, as well as the kind of seed and varieties tested by other workers do not tally with the test material and methodology of this author. Yet, there is a compromise with the present findings in respect of the general trend of increasing adverse effect of effective pesticidal dosages and particularly the harmful behaviour of BHC and lindane on seedling weight (Lange et al., 1949; Starks and Lilly, 1965 a; Srivastava, 1965).

**Effect on productive tillering**

Effect of pesticides on the tillering of wheat crop has been reported by several workers (Chatterji et al., 1966; Sahni and Butani, 1966; Sachan et al., 1967; Allen, 1971). It appears from the relevant literature that there is no such information on barley crop.

The description of the techniques of the treatments, the insecticides and their dosages tested on wheat by the workers mentioned above do not resemble in one or the other aspect among themselves or with this author. Therefore, a proximate comparison of the present findings with the results of other workers is not possible.
However, a few cues to comprehend the general trend with respect to the effect of some pesticides on tillering can be derived.

The data on the productive tillering of wheat and barley plants following seed treatment with powders and emulsifiable concentrates from the microplot tests in the present findings reveal both the favourable and unfavourable effects of pesticides (Tables 27 to 30). The extent of influence is further associated with the kind of pesticide, its dosage and the seed type. In the present observations, BHC 5 per cent dust applied as 2 kg dry to wheat seed was not harmful to productive tillering but affected only when applied at the rate of 2 or 4 kg with sticker due to increased dosages. BHC 10 per cent dust and 50 per cent wettable powder applied as dry or 2 kg or with sticker at 2 or 4 kg rate was also unfavourable for the formation of ear-forming tillers. It indicates that BHC formulation of higher concentration, obviously increased the amount of the active ingredient which resulted in more severe effects on ear-bearing tillers. Chatterji et al. (1958) did not notice any adverse effect of BHC dust on tillering of wheat plants. Probably the insecticide applied to the soil was diluted to a level not to induce any deleterious effect. Sahni and Butani (1966) also did not notice any significant effect on the
tillering of wheat plants with the seed treatment of BHC 5 per cent dust or BHC suspension. Since the dosages used by them are not known, it is presumed that they were too low to manifest any effect. In the present studies also dry application of BHC 5 per cent dust was innocuous to earing of wheat due to a very low dosage adhered to the seed. The treatment of aldrin emulsion gave maximum tillering, albeit the difference in number was not significant from the control (Sahni and Autani, 1966). Similar results were observed in this work with the same pesticide at all the dosages as compared to control and the lowest dosage of 80 g a.i. showed a non-significant numerical increase from the control. Sachan et al. (1967) with aldrin dust at various dosages did not find hampering in the tillering of wheat plants. Application of aldrin dust in the present studies at all the rates did not decline the number of ear-forming tillers in wheat. However, these authors did not find any adverse effect of BHC 10 per cent dust whereas the present observation do not support them. The reason for such deviation may be the differences of the variety of seed and the levels of toxicant remained in contact with the seed. The same authors found that chlordane dust was highly detrimental and no tillering was observed at the dosage level of 50 and 75 lb a.i. per acre but the dosage of 25 lb a.i. per acre gave as good tillering as in control. The results
obtained here also show that application of chlordane dust at the rate of 2 kg dry was not averse to productive tillering in comparison to control but the increase in dosage with the application of 2 and 4 kg with sticker inhibited it significantly than the control. Although a reduction was observed by this author but it was not as drastic as reported by Sachan et al. (1967). In the results reported here endosulfan seed treatment with powder formulation at all the dosages and with emulsifiable concentrates up to 160 g a.i. dosage did not restrict the production of ear-bearing tillers in wheat significantly from control, except at the highest dosage of 200 g a.i. while Allen (1971) did not find any decline in the tillering following seed treatment of wheat with endosulfan at the dosages tried by him. Further, a vis-a-vis perusal of data on germination and the productive tillering in the present microplot tests disclosed that some pesticidal seed treatments in wheat and barley crop despite being significantly lower in germination than control produced as good number of productive tillers as in control. This is evident in wheat seed treatment with aldrin at the dosage of 200 g a.i. and in barley with the treatment of carbaryl applied at the rate of 2 kg with sticker and also with lindane at the rate of 80 g a.i. and chlorpyrifos and phenthoate applied at the rate of 120 g a.i. Allen (1971) also reported that
despite reduced plant number in methomyl treatment (4 oz per bushel) the tillering of wheat was not affected adversely. Such affect is presumably due to the compensatory phenomenon found in the plants. Thus the findings of Allen (1971) are in partial agreement with the present author in respect of response of endosulfan to tillering and increased tillering with treatments showing less emergence of plants.

Field trials (chemical control of termites)

Seed treatment:

*Wheat:* Pre-sowing soil application of insecticides especially the aldrin or DHC dust is a general recommendation still followed for the control of termites in most of the agricultural crops (Krishnamurthy and Rama Subbiah, 1962; Reddy, 1962; Sankaran, 1962; Ghosh, 1964; Parihar, 1978; Anonymous, 1981). Moreover, seed dressing of wheat has also been attempted with successful results in India by some earlier workers but the dosages of insecticides used by them were quite high (Bindra, 1960; Patel, 1962; Sahni and Butani, 1965; Verma et al., 1974). As a result of further studies in this direction Verma et al. (1975) and Chahal et al. (1976) observed that much lower dosages of aldrin were quite effective in protecting wheat crop from termite infestation. Similar work on the seed
treatment of barley was done by Verma et al. (1979 b) with encouraging results. It is understood that the approach of seed treatment is only meaningful when the quantity of a toxicant is reduced to the extent it remains effective so as to minimize the environmental pollution besides the advantage of low cost and convenience in use.

The results of seed treatment of wheat depicted in Table 15 indicate the significant effectiveness of powders of aldrin 5 per cent @ 1.25 and 2 kg with sticker and also of larvin 75 per cent @ 2 kg with sticker per 100 kg seed for checking termite infestation and increasing the crop yield significantly over the control. Similarly, aldrin emulsifiable concentrate @ 1.2C g a.i. and endosulfan @ 16G g a.i. per 100 kg seed either used alone or spliced with carboxin treatment are significantly effective in reducing termite damage with higher yields in comparison to control. The compound, BPMC used as dust and in emulsifiable form appears a complete failure as no improvement in checking termite damage and yield over the control was observed.

Seed dressing with aldrin 5 per cent dust @ 2C to 4C lb per acre of wheat seed was advocated by Bindra (1967) which is too high as compared to the recommendation of Verma et al. (1975) who found dry mixing of aldrin
5 per cent dust @ 1.25 kg (62.5 g a.i.) per 100 kg wheat seed enough in improving crop yield over the control against termite attack. In the present findings dry mixing of aldrin 5 per cent dust @ 1.25 kg per 100 kg seed of wheat although better than control (Table 31), the same dosage applied with sticker is significantly superior than dry application. The results of the author are in conformity with the investigations of Verma et al. (1975) in as much as the effectiveness of dry application of aldrin over control is concerned. However, in the present work better performance obtained with the use of sticker is due to the higher loading of the applied insecticide while in dry application the adherence is not only initially less but a certain amount of toxicant is further lost due to fall off in transfer or transit until sowing. Among the powder treatments a new carbamate compound, larvin 75 per cent w.p. applied at the rate of 2 kg with sticker has given promising results over the control. It has not earlier been tested against termites. Therefore, the suitability of this compound worked out in this study against termites is an additional information for practical recommendation.

Seed treatment of wheat with emulsifiable concentrate of aldrin was found to be very effective against termites.
by Sahni and Butani (1966) and Verma et al. (1974) but the dosages of one litre and 1.25 kg a.i. per hectare, respectively, are high. Another study by Verma et al. (1975) indicated that aldrin @ 125 g a.i. was quite effective against termites in wheat crop. Chahal et al. (1976) tested the dosage of 4 and 8 ml aldrin 30 per cent emulsifiable concentrate per kg seed (equivalent to 120 and 240 ml a.i. per 100 kg seed) and recommended the latter dosage in view of their successful results. The present results support the findings of Verma et al. (1975) as aldrin @ 120 g a.i. gave very good results. In addition to aldrin, the effectiveness of endosulfan emulsifiable concentrate @ 160 g a.i. has been established which was not tested by earlier workers. Moreover, the treatment of aldrin or endosulfan followed by the coating of carboxin reveal their physical compatibility as no significant differences occurred in termite damage or yield as compared with the treatments of aldrin or endosulfan alone. Thus these results substantiate the practical application of combining carboxin with aldrin or endosulfan for seed treatment.

The economics of the treatments is shown in Table 41 where the treatment of larvin wettable powder has been excluded for want of rates as it is in experimental stage of testing. Moreover, carboxin treatment has also been
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatment and dosage per quintal seed</th>
<th>Yield* (q/ha)</th>
<th>Total** (₹/ha)</th>
<th>Cost of treatment (₹/ha)</th>
<th>Net income over control (₹/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Aldrin 5% dust + 1.25 kg with sticker</td>
<td>30.12</td>
<td>5421.60</td>
<td>31.88</td>
<td>1654.72</td>
</tr>
<tr>
<td>2.</td>
<td>Aldrin 5% dust + 2 kg with sticker</td>
<td>31.17</td>
<td>5616.60</td>
<td>39.00</td>
<td>1636.60</td>
</tr>
<tr>
<td>3.</td>
<td>Aldrin e.c. @ 120 g a.i.</td>
<td>32.06</td>
<td>5770.80</td>
<td>28.00</td>
<td>2007.80</td>
</tr>
<tr>
<td>4.</td>
<td>Endosulfan e.c. @ 160 g a.i.</td>
<td>29.97</td>
<td>5394.60</td>
<td>34.00</td>
<td>1659.60</td>
</tr>
<tr>
<td>5.</td>
<td>Control</td>
<td>20.75</td>
<td>3735.00</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Based on data given in Table 35

** Calculated at the rate of ₹ 180.00 per quintal.
avoided to maintain the uniformity in cost of different treatments. The perusal of these data indicate the order of preference based on net income over control as aldrin emulsifiable concentrate @ 120 g a.i. followed by aldrin 5 per cent dust @ 2 kg with sticker, endosulfan @ 160 g a.i. and aldrin 5 per cent dust @ 1.25 kg with sticker per 100 kg seed. Since the yields obtained in these treatments fall in one group of significance, the merit order of net income over control is tentative because any possible numerical fluctuation in yields may occur to alter the sequence of merit.

This trial was conducted in a termite infested field where none of the diseases like smut, bunt and flag-smut appeared. However, at cultivator's field infested with termites the appearance of such diseases is also common for which a blanket recommendation of carboxin seed treatment is imperative to obtain economic control of these disease. It is in this context that the use of carboxin was tested for physical compatibility with a few insecticidal treatments.

Barley: The data of seed treatment of barley (Table 36) represent the significant effectiveness of powders of aldrin and heptachlor 5 per cent dusts and larvin 75 per cent w.p. @ 2 kg with sticker per 100 kg seed in preventing termite attack with increased yields
over control. The emulsifiable formulation of aldrin and heptachlor applied @ 120 g a.i. or endosulfan @ 160 g a.i. alone or each of them with carboxin @ 150 g a.i. per 100 kg seed are also significantly effective in retarding the infestation with more yield in comparison to control. The compound, BBAC tested in the form of dust or emulsifiable concentrate remained at par with control as also observed in the wheat seed treatment trial (Table 35).

The results of Verma et al. (1979 b) revealed that dry mixing of aldrin 5 per cent dust to barley seed @ 10 g per kg seed (equivalent to 750 g of aldrin 5 per cent dust with the seed used @ 75 kg per hectare) proved better than control in one season but not in another season. The lack of consistency in their results may be presumed due to the use of a low dosage with all chances of fall off of the dry dust in handling the seed until sowing. The dosage of aldrin dust used by the author is more along with the advantage of enhanced loading of the toxicant due to application with sticker. Aldrin emulsifiable concentrate with various dosages was also tested in the seed treatment studies of barley by Verma et al. (1979 b) along with aldrin dust treatment in the same trial. They found the dosage of 10 ml aldrin 30 per cent emulsifiable concentrate per kg seed (equivalent to 168.75 ml a.i. per hectare) as the best
treatment in the two seasons. However, the dosage of 5 ml aldrin 50 per cent emulsifiable concentrate (equivalent to 112.5 ml a.i. per hectare) was also better than control in one season. The dosage of 120 g a.i. used here is most effective and corroborate to a great extent with the results of Verma et al. (1979b). Another outcome of the present studies is that besides aldrin formulations, the treatments of heptachlor dust and emulsifiable concentrates of heptachlor and endosulfan have given equally significant results which has offered a new alternative choice of the chemical. Further the treatments of emulsifiable concentrates of aldrin, endosulfan and heptachlor in conjunction of carboxin demonstrated their feasibility for the control of termite infestation without any drawback.

The economics of the treatments presented in Table 42 indicate a maximum net income over control with aldrin emulsifiable concentrate @ 120 g a.i. followed in decreasing order by heptachlor emulsifiable concentrate @ 120 g a.i., endosulfan emulsifiable concentrate @ 160 g a.i., aldrin 5 per cent dust @ 2 kg with sticker and heptachlor 5 per cent dust @ 2 kg with sticker. But this situation is liable to vary because of the fluctuation in yields under field conditions due to the fact that they all fall in the same group of
### Table 42

Economics of insecticidal seed treatment for the control of termites in barley crop

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatment and dosage per quintal seed</th>
<th>Yield* (t/ha)</th>
<th>Total** income (Rs/ha)</th>
<th>Cost of treatment (Rs/ha)</th>
<th>Net income over control (Rs/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Aldrin 5% dust 2 kg with sticker</td>
<td>28.93</td>
<td>4050.20</td>
<td>39.00</td>
<td>1025.00</td>
</tr>
<tr>
<td>2.</td>
<td>Heptachlor 5% dust 2 kg with sticker</td>
<td>28.17</td>
<td>3943.80</td>
<td>38.00</td>
<td>919.60</td>
</tr>
<tr>
<td>3.</td>
<td>Aldrin e.c. 120 g a.i.</td>
<td>30.55</td>
<td>4277.00</td>
<td>28.00</td>
<td>1262.80</td>
</tr>
<tr>
<td>4.</td>
<td>Heptachlor e.c. 120 g a.i.</td>
<td>30.19</td>
<td>4226.60</td>
<td>35.00</td>
<td>1205.40</td>
</tr>
<tr>
<td>5.</td>
<td>Endosulfan e.c. 160 g a.i.</td>
<td>28.97</td>
<td>4055.80</td>
<td>34.00</td>
<td>1035.60</td>
</tr>
<tr>
<td>6.</td>
<td>Control</td>
<td>21.33</td>
<td>2986.20</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Based on data given in Table 36

** Calculated at the rate of Rs 140.00 per quintal
significance. The use of carboxin, for protecting the crop from covered or loose smut or barley stripe disease gives a false impression of an additional burden to the cultivator. However, to cover the risk of these commonly occurring diseases a blanket recommendation has to be followed which will automatically reduce the net income over control in the absence of any disease but will go in favour of the cultivator if the disease appears.

Post-sowing treatment with irrigation:

Prophylactic chemical control measures are not followed at times either due to some unavoidable circumstances or merely by negligence which may result in the occurrence of termite infestation in the wheat crop. Further in areas where termite infestation remains within tolerable limits may increase during a favourable season. Under all these conditions it becomes imperative to adopt control measures in the standing crop. Soil application of persistent chlorinated hydrocarbons along with irrigation is usually followed for this purpose. Formerly the application of aldrin 30 per cent emulsifiable concentrate at the rate of 5 litres per hectare was the common recommendation with irrigation (Anonymous, 1972, 1974, 1975). In Rajasthan also the use of aldrin 30 per cent emulsifiable concentrate at the rate of 4 litres or lindane 20 per cent emulsifiable concentrate at the rate of 5 litres per hectare was
advocated (Anonymous, 1978). These dosages were experienced to be too high and expensive. Probably with this background, experiments were conducted in Punjab (Sandhu and Sohi, 1977) which revealed that equally good protection to standing wheat crop from termites can be achieved by lower dosages of aldrin with irrigation. During present studies also the results of the initial trial (Table 37) on wheat crop indicated that 400 g a.i. of aldrin, lindane and heptachlor or 600 g a.i. of chlordane per hectare along with first irrigation were as good as the higher dosages of these insecticides up to 1000 g a.i. Further assessment of lower dosages of these insecticides during another season confirmed the effectiveness of aldrin, lindane, heptachlor and chlordane. Application of aldrin even at 300 g a.i. was at par with 400 g a.i. of the same insecticide (Table 38).

Differential effectiveness of lower dosages of aldrin has been reported from Haryana (Verma et al., 1974) and Punjab (Sandhu and Sohi, 1977). In Punjab even the lowest tried dosage of 0.625 litres of 30 per cent aldrin per hectare (equivalent to 187.5 ml a.i.) was found as effective as 5 litres (equivalent to 1500 ml a.i.) of the same formulation. While in Haryana aldrin at the dosage of 625 g a.i. per hectare (approximately 2 litres of 30 e.c.) was slightly inferior
to 1.25 g a.i. per hectare dosage (approximately 4 litres of M e.c.) on the grain yield basis but did not differ significantly in infestation level. Thus the present results support the investigations of other workers regarding the efficacy of lower dosages of aldrin and further suggest the effectiveness of heptachlor, lindane and chlordane at much lower rates than the conventional rates of recommendation. Moreover, from a comparison of the data of economics (Table 43) of the treatments it is construed that aldrin @ 400 g a.i. is most profitable followed by heptachlor @ 400 g a.i. aldrin @ 300 g a.i., chlordane @ 600 g a.i. and lindane @ 400 g a.i. per hectare. But the differences of net return within these treatments are tentative being worked out on the observed grain yield differences which are non-significant and with the present cost of insecticides which are variable.

Mound treatment:

Application of insecticides for the control of mound-building termites is an easy, effective and economical proposition for the management of termite population especially in endemic areas. Attempts for the destruction of mound-building termites have been made by earlier workers (Beeson, 1941; Roonwal, 1951; Singh and Shanna, 1957; Bindra, 1960; Roonwal and
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Treatments</th>
<th>Dosage g a.i. per ha</th>
<th>Yield* of wheat (q/ha)</th>
<th>Total** income (Rs./ha)</th>
<th>Cost of treatment (Rs./ha)</th>
<th>Net income over control (Rs./ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Alorin</td>
<td>400</td>
<td>29.23</td>
<td>5261.40</td>
<td>108.69</td>
<td>1687.71</td>
</tr>
<tr>
<td>2.</td>
<td>Aldrin</td>
<td>300</td>
<td>28.50</td>
<td>5130.00</td>
<td>88.50</td>
<td>1576.50</td>
</tr>
<tr>
<td>3.</td>
<td>Chlordane</td>
<td>600</td>
<td>28.95</td>
<td>5211.00</td>
<td>170.00</td>
<td>1576.00</td>
</tr>
<tr>
<td>4.</td>
<td>Heptachlor</td>
<td>400</td>
<td>28.93</td>
<td>5207.00</td>
<td>77.00</td>
<td>1665.00</td>
</tr>
<tr>
<td>5.</td>
<td>Lindane</td>
<td>400</td>
<td>28.05</td>
<td>5049.00</td>
<td>120.00</td>
<td>1464.00</td>
</tr>
<tr>
<td>6.</td>
<td>Control</td>
<td>-</td>
<td>19.25</td>
<td>3465.00</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Based on data given in Table 38

** Calculated at the rate of Rs. 180.00 per quintal
Chatterjee, 1960). These workers used the dusts, emulsifiable concentrates and mainly wettable powders. Barring, Roomwal and Chatterjee (1960) the early workers, irrespective of the mound volume used despotic quantities of water for drenching the poisons into the termitaria. As pointed out by Roomwal and Chatterjee (1960), both the concentration of the toxicant and the total volume of liquid poured into the termitarium are vitally important for the net performance of this method. During present studies volumes of liquid ranging from 10 to 40 litres per cubic metre of mound volume were tested in a pilot experiment where 30 litres was found to be optimum in the area of experimentation (loamy sand soils).

Of the four chlorinated hydrocarbons evaluated under present studies, aldrin 3C e.c. @ 20 ml and heptachlor 2C e.c. @ 30 ml with 30 litres of water per cubic metre mound volume destructed all the termitaria. Aldrin has earlier been reported to be very effective against several species of Odontotermes (Singh and Sharma, 1957; Bindra, 1960; Roomwal and Chatterjee, 1960). Heptachlor was tested for the first time in the present studies and can be substituted for aldrin, though the latter one has a premium over the former from cost view point. Lindane and chlordane provided only
and 70.00 per cent control, respectively, and as such cannot be recommended. Pouring of phorate granules alone was less effective unless water drenching preceded the granular application for better distribution and effectiveness of the toxicant. Rajagopal and Veeresh (1978) obtained complete control of *Odontotermes wallonensis* (Wasmann), with phorate granules alone. The differences in the performance as compared with the present results may be attributed to the variations in the composition of the mound soils, humidity and temperature inside the mound in different climatic zones of the country and the species of termites involved in experimentation. Rajagopal and Veeresh (1978) got excellent results with phorate alone at Bangalore where the soils are heavier and the climate is more humid as compared to Jaipur district where the soils are loamy sand and the climate is relatively dry (semi-arid).

Drenching of all the inhabited termitaria in the vicinity of wheat crop at Manoharpur with aldrin emulsion resulted in 49.10 to 70.45 per cent reduction in termite infestation during the next season (Table 4C). Total protection in the crop could not be achieved since another subterranean termite, *Microtermes obesi* was also involved in the field. Sands (1973) also emphasized that direct destruction of the mound-building termite
nests have a limited scope in obtaining complete control of the termites especially when some other non-mound building termites are also involved in attacking the crop. In such cases only part of the damage will be checked. The present findings upheld the view experienced by Sandos (1975) as this method cannot be solely relied upon for the complete protection of the crop from termites. Still the method being easy and cheaper must be exploited even in the existence of some other subterranean species for the regulation of termite population in areas where mound-building termites are responsible for crop damage.

The cost of mound extermination through insecticides ranged between Rs. 1.90 to Rs. 2.40 per cubic metre of mound volume as shown in Table 44. The most effective treatments are emulsions of aldrin and heptachlor where the expenses for destruction per cubic metre mound being Rs. 2.20 and Rs. 2.40, respectively, are not exorbitant in view of the perennial advantage of protection of crop from the ravages of mound inhabiting termites.
### TABLE 44

Cost of colony extermination per cubic metre of mound volume

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Formulated dosage per cu.m. ml/gr</th>
<th>Rate per lit/kg</th>
<th>Cost insecticides Rs</th>
<th>Of Labour Rs</th>
<th>Total expenses Rs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aldrin 30 e.c.</td>
<td>20</td>
<td>70.00</td>
<td>1.40</td>
<td>0.80</td>
<td>2.20</td>
</tr>
<tr>
<td>Chlordane 20 e.c.</td>
<td>30</td>
<td>47.00</td>
<td>1.41</td>
<td>0.80</td>
<td>2.21</td>
</tr>
<tr>
<td>Heptachlor 20 e.c.</td>
<td>30</td>
<td>56.00</td>
<td>1.58</td>
<td>0.80</td>
<td>2.40</td>
</tr>
<tr>
<td>Lindane 20 e.c.</td>
<td>30</td>
<td>50.00</td>
<td>1.50</td>
<td>0.80</td>
<td>2.30</td>
</tr>
<tr>
<td>Phorate 10 G</td>
<td>50</td>
<td>22.00</td>
<td>1.10</td>
<td>0.80</td>
<td>1.90</td>
</tr>
</tbody>
</table>

* Two labourers paid Rs. 10.00 per day
cover 25 termitaria each day.