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Long-Range Effects of Chlorflurenol on the Sex Organs of Linseed

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Chlorflurenol (a morphactin) was applied to linseed plants in five concentrations (6.25, 12.5, 25, 50 and 100 ppm) in one or two foliar sprays when the plants were five weeks old. As the flowers were at different stages of development during a 8-week period of observation, these were divided into five stages (I–IV and 'fruits'). The percentages of flowers showing modified stamens and pistils at different stages of development were recorded periodically.

During the first two weeks, stamens in flowers of stages I and II were unaffected. However, some morphological changes were noticed in a few treatments in flower buds of stages III and IV. The pistil showed an increase in the number of styles in stage I. In stage II the pistils were basally connate but apically free, exposing the ovules. More variations in the morphology of the pistil had occurred at stage III as compared to stages I and II. Flowers were less affected at stage IV than at others.

At the end of four weeks both stamens and pistils were modified even in flowers of stage I and II. Poor development or total suppression of pistil was seen in stage III. Stamens showed varied responses.

Six weeks after application, flowers of stages I–III showed either total absence or poor development of the stamens. These were most prominent at 100 ppm (2 sprays). It was at this period that male sterility was most pronounced.

The flower buds of stage IV showed normal stamens and pistils, twinning of the ovary, and increased number of carpels. In most of the treatments pistil was normal at stage III.

Data collected 8 weeks from the start showed that whereas 42–100% of the flowers of stage I had poorly developed stamens or were stamenless, twining of the ovaries and presence of two whorls of carpels were commonly observed. In the flower buds of stages II–IV stamen and pistil development was normal.

Key Words: Chlorflurenol, Growth regulators, Morphactin, *Linum usitatissimum*, Linseed, Sex expression

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Introduction

A survey of the literature on the effects of morphactins on flower development shows that whereas short-term formative changes brought about by morphactins have been listed and illustrated (Merck Technical Information Sheet 1965, Harada 1968, Sankhla & Sankhla 1968, Sankhla et al. 1975, Denffer et al. 1969, Schneider 1972, Bojan et al. 1980) no systematic study of the long range effects of various concentrations and number of sprays of morphactin has been made, especially in relation to time after application. A detailed account of the various morphological changes by chlorflurenol on the components of the capitulum of *Calendula officinalis* has, however, been published recently (Mehta & Mohan Ram 1979). In the present investigation, details of the modification of the stamens and pistils at various stages of flower development in linseed in response to treatments have been studied and the male sterility response caused by one of the morphactins, namely chlorflurenol has been evaluated.

Material and Methods

Chlorflurenol (morphactin IT 3456 or methyl-2- chloro- 9- hydroxyfluorene- 9- carboxylate) was applied to the plants of *Linum usitatissimum* L. variety N.D. (R.R.) 9 in five concentrations i.e. 6.25, 12.5, 25, 50 and 100 ppm in 1 or 2 sprays. The first spray was given when the plants were five weeks old and the second spray one week later. The chemical was sprayed on the foliage in the evening with a foot-operated sprayer until the point of run off. Triton X-114 (0.02%) was used as the surfactant.

The linseed flowers are produced continuously for 6 weeks. The observations on flower morphology were restricted to the central basal branch only. Data were collected from five central branches for each treatment. The observations were recorded four times, at two-week intervals. Information obtained this way made it possible to compare the effects of the treatment (concentrations and number of sprays) in relation to time. Any recovery from the treatment was also assessed by this method.

During the period of study flowers were found to be at different stages of development. In order to make a comparative estimate of the effects, these were divided into five stages (stages I–IV and 'fruits') on the basis of the size and age (figure IA–D). Although the stages have been recognized on the basis of control plants, flower size could not be taken as the sole criterion for determining the stages in treated plants as chlorflurenol caused variform reduction in size. The extent of development of the floral organs and anthesis had also to be considered.

A brief description of the control flowers of each stage is given below:

Stage I: Open flowers (figure 1A) with stamens reaching up to the level of the stigma (figure 1E); anthers dehisced or undehisced; styles open or closed and twisted (figure 1F).

Stage II: Flower buds one day before anthesis, 1.1–1.2 cm long; corolla protruding beyond the calyx (figure 1B); petals twisted. Filaments short, anthers below the level of stigma and undehisced.

Stage III: Young flower buds 0.7–0.9 cm long (excluding the pedicel) (figure 1C); corolla completely enclosed within the calyx. Anther lobes, styles and ovary well-developed but filaments short.

Stage IV: Flower buds 0.5–0.6 cm long (figure 1D); narrower than in figure 1C and with sharp and narrow tip; corolla completely enclosed within the calyx. Anther lobes, styles, and ovary well-developed, but filaments short.

Flower buds shorter than 0.5 cm in length were not included in the above categories as they were difficult to dissect. All stages after petal shedding till maturity of fruits have been considered as 'fruits'.

Observations

Flowering started at the same time in the control and treated plants. Prolongation of the flowering period was, however, observed in the latter (excepting at 50 and 100 ppm, 2 sprays). There was evidence that it was flower development rather than flower initiation that was greatly arrested or modified.

Various modifications in flower structure were noted in response to treatments. First the general responses will be described. The detailed quantitative analysis of the responses of the reproductive organs in the flower buds of various stages of development to applied chlorflurenol would be dealt later.

General responses

Shortening of the pedicels, fasciation of the inflorescence axis and ontogenic fusion of the flower buds (figure 1G) were observed in some instances. Reduction in size and lack of anthesis of flowers were occasionally noted. The calyx was gamo- or polysepalous, with a reduction in the number and enlargement of one or more sepals.

The sepals became fleshy and their vasculature prominent. The corolla was partially or completely fused. Occasionally the number of petals was increased and these were arranged in two whorls. Reduction in the width of the petals was also a common feature.

In nature the flowers borne by an individual plant are either blue or white. In the treated plants, however, the same plant was observed to bear both white and blue flowers. One common feature observed in the flowers of the treated plants was the extreme elongation of the torus (floral axis). This could occur above the region of insertion of the stamens, petals or even of sepals. The stamens and pistils were greatly modified. The stamens were either totally suppressed (figure 1I) or were represented by unequal anther lobes showing partial suppression of development of microsporangia (figure 1H). In some instances the contents of the anther sac appeared completely degenerated (*see* microsporangium on top left in figure 1M) or the pollen were clumped together and showed a high degree of enlargement and vacuolation. Reduction in the length of the stamens was commonly associated with their fusion with the ovary wall (figure 1H).

In some rare instances petals were observed to differentiate anther lobes bearing normal pollen grains. Very rarely, ovules developed from the base of a filament. In some flowers the initiation of pistil and stamen primordia had occurred but their differentiation had been arrested. In a few flowers the pistil was well-developed but the stamens were totally suppressed (figure 1J) and in some the stamens were normal but the pistil was suppressed. Severa deviations in the development of the pistil were noted (figure 1K). At times the axis of the flower extended beyond the ovary to form another ovary (figure 1L). In certain flowers three pistils could be seen in a vertical row on a common axis (figure 1O). In these instances the ovules of the terminal and often the middle ovary became exposed (figure 1O). Whereas the seeds developing within the locules contained mature embryos, those which were exposed (in the same ovary) showed embryos which were not only younger but also smaller than the normal embryos. In some instances the base of the ovary became massive and parenchymatous and the ovules degenerated. In others the ovary wall became so greatly thickened that

it almost obliterated the development of the locules. At times the ovary appeared normal externally but showed degenerated ovules within. An extreme condition was noted in which the ovary was filled with a parenchymatous tissue without any sign of differentiation of locules or ovules. The fusion of styles was a common feature (figure 1J,P). Whereas in the pistils of control flowers there were usually 10 pendulous, anatropous, ovules borne by the tip of the axial placentae, in the treated plants only 3 or 4 orthotropous ovules were seen in the same position (figure 1P). A few rare instances of supernumerary carpels with apocarpous condition were also noted (figure 1M).

Since the principal objective of this work was to establish whether or not chlorflurenol could induce selective male sterility, it became necessary to make a detailed analysis of the extent of modification of the stamens and pistils at various stages of flower development in response to treatments. Several criteria were used for establishing the chlorflurenol effects. The most significant features of the data collected at 14 day intervals have been presented in tables 1 and 2. Owing to the overlapping responses produced by chlorflurenol the description of the data is somewhat repetitious.

In general, the stamens and pistils became variously modified in treated plants and the effects were somewhat similar, irrespective of the dosage of chlorflurenol used. However, stamens and pistils of control plants analysed any time during the period of observation were normal.

Quantitative analysis of the responses

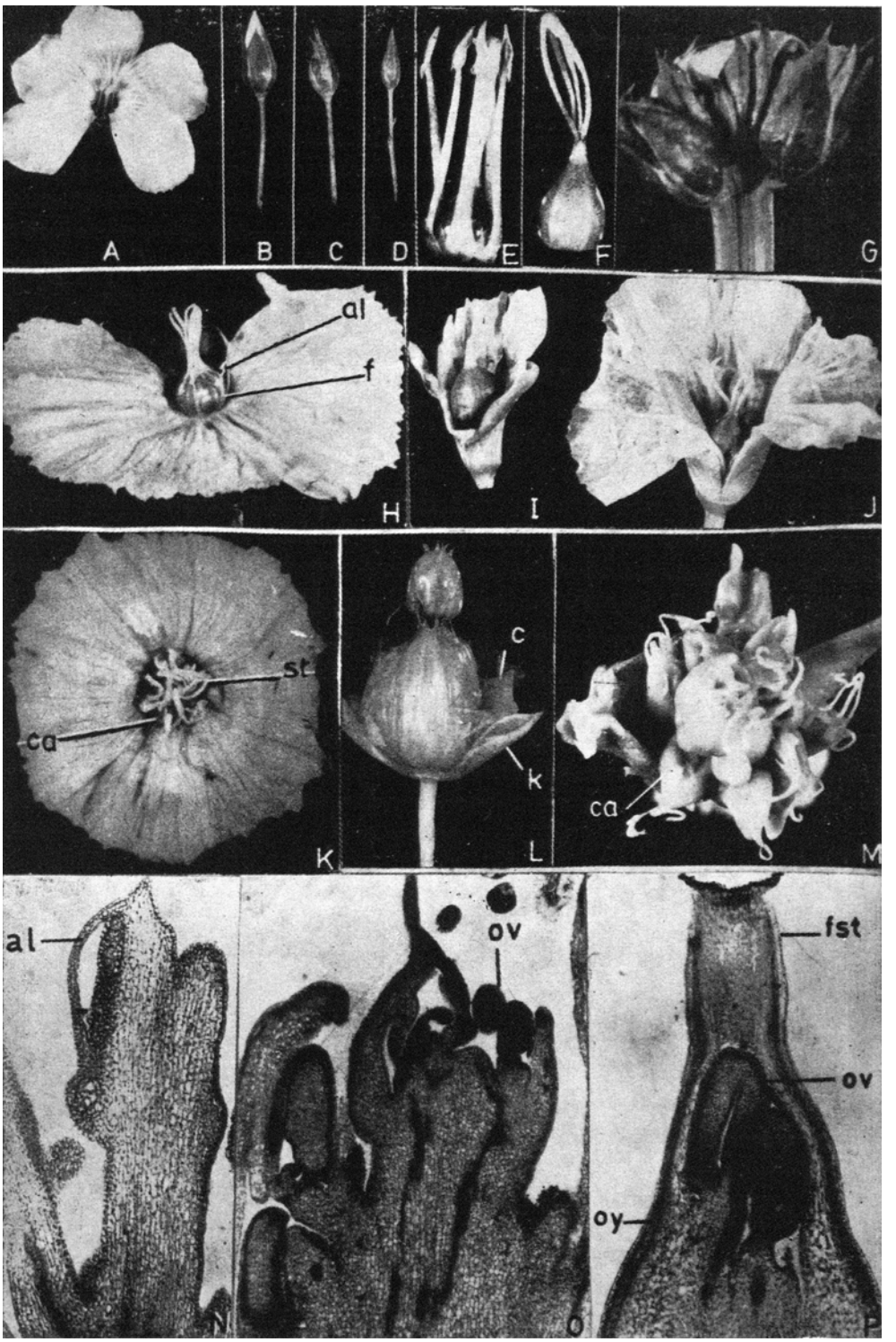
Observations made 14 days after the second spray (see tables 1 and 2)

Flowers of stage I: One hundred per cent of the flowers at stage I had normal stamens in all treatments excepting 12.5 ppm (2 sprays) and 100 ppm (2 sprays). In these concentrations shortening of the filaments and fusion of the anthers with ovary was noted. Since this condition can interfere with self-pollination, it can be considered an important modification. The pistils at this stage remained unaffected or mildly affected i.e. abnormalities were restricted to a change in the number of styles or size of the pistil.

Flower buds of stage II: At all concentrations excepting 100 ppm (1 and 2 sprays) and 12.5 ppm (2 sprays) 100% of the flowers showed normal stamens. At 12.5 ppm (2 sprays) 29% of the flower buds showed absence or poor development of the stamens. At 100 ppm (1 and 2 sprays)

Figure 1 A–P *Linum usitatissimum*:
A-D, Stages I, II, III and IV respectively of flower development. (These have been used as standards in text) (×1.5); *E*, Control flower of stage I from which sepals and petals have been removed (×3.5); *F*, Pistil from control flower showing twisting of the styles (stage I) (× 3.5); *G*, The axis has become flattened and shows several fused flower buds at the apex in response to chlorflurenol treatment (× 1); *H*, Flower showing a fan-shaped corolla and normal pistil. The two stamens have short filaments (f) which have become fused with the ovary and the anther lobes (al) are highly reduced (× 1.3); *I, J*, Stamen-less flowers (× 2); *K*, Top view of a flower with increased number of carpels (ca). Note the supernumerary styles (st) (× 1.5); *L*, An instance of two superposed fruits developed from the same flower (× 2.7); *M*, Top view of a flower with two superposed pistils in which the lower one is showing apocarpous condition and the upper a syncarpous condition (×2.5); *N*, L.s. part of treated flower showing sterilization of one of the anther lobes (al) (× 20); *O*, L.s. part of a flower. Note three pistils in a vertical row; the ovules (ov) in the top and middle pistil are exposed (× 19.3); *P*, L.s. part of a treated pistil. The ovules are orthotropous and the styles are fused (fst) to form a solid structure (× 22.3);

(**al**, anther lobe; **c**, corolla; **ca**, carpel; **f**, filament; **fst**, fused style; **k**, calyx; **ov**, ovule; **oy**, ovary; **st**, style)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the flowers showed increased number of stamens short filaments and fusion of anthers with ovary, although the percentage of such flowers was only 9–14 (table 1). The pistil was either totally absent or poorly developed in plants treated with chlorflurenol at 6.25 ppm (1 spray), 25 ppm (1 spray) and 50 ppm (2 sprays). Free carpels with exposed ovules were observed during this period in a small percentage of treated flowers (table 2).

Flower buds of stage III: One hundred per cent of the flowers had normal stamens at 6.25 ppm (2 sprays), 12.5 ppm (2 sprays), 25 ppm (1 and 2 sprays) and 50 ppm (2 sprays). Total suppression of the stamens was not observed in response to any treatment. However, at 6.25 ppm (1 spray) and 100 ppm (1 and 2 sprays) 16–29% of the flower buds had a higher number of stamens, which were abnormal. Besides this at 6.25 ppm (1 spray) and 12.5 ppm (1 spray) 31–33% of the flower buds had miscellaneous abnormalities (table 1). The pistil was either absent or poorly developed (19–43%) in all the concentrations except at 6.25 ppm (2 sprays) and 25 ppm (2 sprays) (table 2). Interestingly at 6.25 ppm (1 spray) no flower bud had normal pistil. Various modifications such as reduction in the size of the pistil, change in the number of styles and fusion of styles were also observed.

Flower buds of stage IV: Normal stamens were observed in all the treatments except at 6.25 ppm (1 spray) and 12.5 ppm (1 spray). Curiously, not a single flower bud of stage IV was available in the plants given 2 sprays at 50 ppm (table 1).

Total absence or poor development of pistil was observed in a high percentage of the treated flowers. However, at 25 ppm (1 spray) and 100 ppm (1 and 2 sprays), 100% of the flower buds had normal pistil. Other variations such as change in the number of styles and size of the pistil were observed in 33–66% of the flower buds.

Observations made 28 days after second spray (tables 1, 2)

Flowers of stage I: In general a wider range of modifications were noticed in the stamens of treated plants. The percentage of flowers showing normal stamens was low in all the concentrations except 25 ppm (1 spray) and 100 ppm (1 spray). Total elimination or poor development of stamens was noted during this period in response to certain concentrations of chlorflurenol (table 1). A high percentage of flowers (33–83) showed a change in the number and also abnormality of stamens, except in response to 25 ppm (1 spray).

A high percentage of flowers (57–83) showed either total suppression or poor development of the pistils at 12.5 ppm (1 spray), 50 ppm (1 spray), 25 ppm (2 sprays) and 100 ppm (1 spray). At 50 ppm (2 sprays) no flower had normal pistil (table 2).

Flower buds of stage II: Normal stamens were absent in treatments other than 25 ppm (2 sprays), 50 ppm (2 sprays) and 100 ppm (1 and 2 sprays). Fifty per cent of the flower buds showed full or partial inhibition of stamen development at 100 ppm (1 spray). At other concentrations flower buds showing a similar abnormality ranged from 8 to 33%. A change in the number of stamens, accompanied by different types of modification was also commonly observed during this time (table 1).

In a high percentage (66–100) of flower buds of stage II, the pistils were poorly developed or absent at 6.25 ppm (1 spray), 25 ppm (2 sprays), 50 ppm (1 spray) and 100 ppm (2 sprays).

Flower buds of stage III: The percentage of flower buds bearing normal stamens was low (14–33%) in most of the treatments

(table 1). However, at 12.5 ppm (2 sprays) and 100 ppm (2 sprays), 50 and 67% of the flower buds had normal stamens respectively. Seventy-five per cent of the flower buds in plants treated with 25 ppm (2 sprays) showed either total inhibition or poor development of the stamens. The percentage of flowers exhibiting various other modifications is listed in table 1.

Poor development of pistils or absence of pistils was noted in a high percentage (50–100) of flower buds in most of the concentrations. At 100 ppm (2 sprays) 67% of the flower buds had normal pistils. In other treatments, however, flower buds with normal pistil were either absent or present in a very low percentage (table 2).

Flower buds of stage IV: Flower buds of this stage were present only in plants given 6.25 ppm (2 sprays). These had normal stamens and either no pistils or only incompletely developed pistils.

Observations made 42 days after second spray

Flowers of stage I: At this time of observation, all the treated plants showed either no stamens or stamens which were poorly developed, although the percentage of flower buds representing such a condition varied from 23–100% (table 1). Stamens were highly modified in all the treatments.

Pistil growth was markedly curtailed during this time and the percentage of flowers representing this feature was variable (7–100). However, instances of increased number of carpels and the presence of double ovary were noted for the first time in all concentrations excepting 50 ppm (2 sprays) and 100 ppm (1 and 2 sprays). The percentage of the flowers representing other types of modifications are listed in table 2 against column D.

Flower buds of stage II: Complete elimination or reduction in the number of stamens was noticed in a large number of the flowers (41–100%). At the same time enhancement in the number of stamens showing various abnormalities was commonly observed in many of the treatments (table 1). In a high percentage (42–100) of the flowers borne on the treated plants, the pistil development was wholly or partially suppressed (table 2). At 6.25 ppm (1 spray) and 25 ppm (1 spray), 6 and 24% of the flowers respectively showed an increase in the number of carpels or presence of a double ovary.

Flower buds of stage III: Flower buds bearing normal stamens were higher (55–100%) in all the treatments excepting at 25 ppm and 100 ppm (1 and 2 sprays). At 25 ppm and 100 ppm (1 spray) only 33% and 25% of the flower buds respectively had normal stamens. At 25 ppm, 50 ppm and 100 ppm (2 sprays) flower buds of stage III were absent.

A high percentage (91–100) of flower buds had normal pistil at 6.25 ppm (1 and 2 sprays), 50 ppm (1 spray) and 100 ppm (1 spray). At 25 ppm (1 spray) 67% of the flower buds showed total elimination or poor development of the pistil.

Flower buds of stage IV: Flower buds of stage IV were present only in plants sprayed with 6.25 ppm (1 spray), 12.5 ppm (2 sprays) and 25 ppm (1 spray). In these treatments all the flower buds had normal stamens and pistils.

Observations made 56 days after second spray (tables 1, 2)

In the control plants flowering had stopped by this time. Plants given 2 sprays of chlorflurenol at 50 ppm and 100 ppm had dried up.

Flower of stage I: In all the concentrations excepting 6.25 ppm (1 spray), and 25 ppm (1 spray) flowers showed total elimination or poor development of the

stamens (table 1). An increase or decrease in the number of stamens accompanied by various modifications was observed in many treatments and the percentage of flowers representing this type of abnormality ranged from 14 to 43.

During this period a normal pistil was present in 28–100% of the flowers. In all the treatments barring 6.25 ppm (1 spray) and 25 ppm (1 and 2 sprays), the presence of a double ovary or increased number of carpels was observed (table 2).

Flower buds of stage II: Whereas total absence or poor development of stamens was observed even during this time in some treatments (table 1), in others (6.25 ppm, 1 and 2 sprays; 12.5 ppm, 1 spray; 25 ppm, 1 and 2 sprays) 50–100% of the flower buds had normal stamens.

In all the treatments excepting 50 and 100 ppm (1 spray) the pistil was normal. Even at 50 ppm (1 spray) 50% of the flower buds had normal pistil and 13% of the flower buds showed an increase in the number of carpels or the presence of double ovary (table 2).

Flower buds of stage III: A high percentage of the flower buds (66–100) had normal stamens at 6.25 ppm, 12.5 ppm and 25 ppm (1 and 2 sprays). At 50 ppm (1 spray) 40% of the flower buds had normal stamens and 20% of the flower buds showed poor development or absence of stamens.

A large number of flower buds (80–100%) had normal pistil at all the concentrations excepting 50 and 100 ppm (2 sprays), where the flower buds had dried up.

Flower buds of stage IV: Barring 100 ppm (1 spray) 100% of the flowers had normal stamens. Flower buds also had normal pistil at all concentrations excepting 50 and 100 ppm (2 sprays) in which the plants had dried up.

Discussion

Chlorflurenol caused variform flower morphology in linseed. Calyx and corolla were greatly modified, as was noted in other plants by Schneider (1964, 1969, 1970, 1972), Ringe and Denffer (1967), Sankhla and Sankhla (1968), Sankhla (1969) and Sankhla et al. (1975). The reduction in flower size, observed in chlorflurenol-treated linseed plants was also commonly noted in plants treated with certain gametocidal compounds (Mohan Ram & Rustagi 1966, Rustagi 1967). Chlorflurenol-induced effects such as fusion of petals and prevention of petal abscission, crumpling and folding of petal and lack of anthesis in linseed were comparable to those produced by mendok and dalapon in the same plant (Rustagi 1967). Other common features were shortening of filaments, fusion of anthers, and presence of petaloid stamens.

The petal colour in linseed is controlled by genetic factors and not by environmental conditions (Shaw et al. 1931, Jeswani & Guglani 1963). Chlorflurenol treatment, however, caused the occurrence of blue and white flowers on the same individual plant (present work). This is an unusual finding.

Although some of the effects produced by chlorflurenol on linseed were common with those caused by mendok or dalapon, there were certain modifications in pistil development which were unique to chlorflurenol. The most striking finding was the differentiation of a vertical row of twin or triple ovaries. There are reports of production of extra whorls of carpels or presence of an additional ovary resulting from the fusion of buds (Sankhla & Sankhla 1968, Jayakaran 1972). In the instances cited above the extra whorl of carpels is situated adjacent to the original ovary. In chlorflurenol-treated linseed plants (present work), however, the whorl of carpels was produced by the extension of the central axis of the same flower.

Table 1 *Effect of Chlorflurenol on Stamen Development (Figures represent per cent of flowers showing a particular response)*

Days after second spray	Types of response	Stage of flower development*	Treatments: 0 ppm (control)				6.25 ppm: 1 spray				6.25 ppm: 2 sprays			
			I	II	III	IV	I	II	III	IV	I	II	III	IV
14	A		100	100	100	100	100	100	38	17	100	100	100	100
	B		—	—	—	—	—	—	—	—	—	—	—	—
	C		—	—	—	—	—	—	29	83	—	—	—	—
	D		—	—	—	—	—	—	33	—	—	—	—	—
28	A		100	100	100	100	18	—	—	NP	17	—	—	100
	B		—	—	—	—	—	8	—	NP	17	—	50	—
	C		—	—	—	—	73	23	29	NP	66	—	50	—
	D		—	—	—	—	9	69	71	NP	—	100	—	—
42	A		100	100	100	NP	—	12	55	100	—	14	80	NP
	B		—	—	—	NP	71	47	9	—	55	57	—	NP
	C		—	—	—	NP	17	23	—	—	45	14	—	NP
	D		—	—	—	NP	12	18	36	—	—	14	20	NP
56	A		NP	NP	NP	NP	67	100	100	100	17	67	100	100
	B		NP	NP	NP	NP	—	—	—	—	66	33	—	—
	C		NP	NP	NP	NP	—	—	—	—	—	—	—	—
	D		NP	NP	NP	NP	33	—	—	—	17	—	—	—

Days after second spray	Types of response	Stage of flower development*	Treatments: 12.5 ppm: 1 spray				12.5 ppm: 2 sprays			
			I	II	III	IV	I	II	III	IV
14	A		100	100	69	50	67	71	100	100
	B		—	—	—	—	—	29	—	—
	C		—	—	—	42	33	—	—	—
	D		—	—	31	8	—	—	—	—
28	A		8	—	14	NP	—	—	50	NP
	B		8	—	14	NP	17	17	—	NP
	C		54	25	—	NP	33	33	—	NP
	D		30	75	71	NP	50	50	50	NP
42	A		3	—	100	NP	—	—	75	100
	B		65	88	—	NP	23	43	—	—
	C		28	—	—	NP	69	57	—	—
	D		3	12	—	NP	8	—	25	—
56	A		—	50	67	100	—	—	100	100
	B		100	—	—	—	79	100	—	—
	C		—	—	—	—	21	—	—	—
	D		—	50	33	—	—	—	—	—

Days after second spray	Types of response	Stage of flower development*	Treatments: 25 ppm: 1 spray				25 ppm: 2 sprays			
			I	II	III	IV	I	II	III	IV
14	A		100	100	100	100	100	100	100	100
	B		—	—	—	—	—	—	—	—
	C		—	—	—	—	—	—	—	—
	D		—	—	—	—	—	—	—	—
28	A		57	—	29	NP	29	22	25	NP
	B		—	—	—	NP	28	33	75	NP
	C		14	67	—	NP	43	—	—	NP
	D		29	33	71	NP	—	45	—	NP
42	A		—	—	33	100	—	—	NP	NP
	B		50	41	67	—	50	55	NP	NP
	C		45	41	—	—	—	45	NP	NP
	D		5	18	—	—	50	—	NP	NP
56	A		50	100	100	100	—	100	100	100
	B		50	—	—	—	86	—	—	—
	C		—	—	—	—	14	—	—	—
	D		—	—	—	—	—	—	—	—

Days after second spray	Types of response	Stage of flower development*	Treatments: 50 ppm: 1 spray				50 ppm: 2 sprays			
			I	II	III	IV	I	II	III	IV
14	A		100	100	100	100	100	100	100	NP
	B		—	—	—	—	—	—	—	NP
	C		—	—	—	—	—	—	—	NP
	D		—	—	—	—	—	—	—	NP
28	A		17	—	—	NP	14	50	33	NP
	B		—	—	—	NP	14	25	—	NP
	C		83	33	—	NP	72	—	—	NP
	D		—	67	100	NP	—	25	67	NP
42	A		—	—	60	NP	—	—	NP	NP
	B		87	96	40	NP	83	100	NP	NP
	C		13	4	—	NP	—	—	NP	NP
	D		—	—	—	NP	17	—	NP	NP
56	A		—	25	40	100	Dried up			
	B		86	25	20	—	,,	,,	,,	,,
	C		14	50	—	—	,,	,,	,,	,,
	D		—	—	40	—	,,	,,	,,	,,

Days after second spray	Types of response	Stage of flower development*	Treatments: 100 ppm: 1 spray				100 ppm: 2 sprays			
			I	II	III	IV	I	II	III	IV
14	A		100	91	83	100	75	86	69	100
	B		—	—	—	—	—	—	—	—
	C		—	9	—	—	25	14	16	—
	D		—	—	17	—	—	—	15	—
28	A		45	50	NP	NP	17	17	67	NP
	B		—	50	NP	NP	—	—	—	NP
	C		55	—	NP	NP	67	67	—	NP
	D		—	—	NP	NP	16	16	33	NP
42	A		—	—	25	NP	—	—	NP	NP
	B		31	75	75	NP	100	100	NP	NP
	C		46	8	—	NP	—	—	NP	NP
	D		23	17	—	NP	—	—	NP	NP
56	A		14	17	—	—	Dried up			
	B		43	67	—	—	,,	,,	,,	,,
	C		43	—	—	—	,,	,,	,,	,,
	D		—	16	100	100	,,	,,	,,	,,

*For details *see* text; NP, Stage not present; —, No response; A, Normal stamens; B, Stamens absent or poorly developed; C, Increase or decrease in the number of abnormal stamens (includes shortening of filaments and fusion of anthers with ovary); D, Miscellaneous (includes features such as: change in the number of normal stamens; fusion of fertile anthers with petals; monadelphous but normal stamens; syngenesious but normal anthers; unequal stamens)

Table 2 *Effect of Chlorflurenol on Pistil Development (Figures represent per cent of pistils showing a particular response)*

Days after second spray	Types of response	Stage of flower development*	Treatments: 0 ppm (control)				6.25 ppm								12.5 ppm							
							1 spray				2 sprays				1 spray				2 sprays			
			I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
14	A		100	100	100	100	100	83	—	17	100	100	86	33	100	100	23	42	67	93	29	30
	B		—	—	—	—	—	11	43	50	—	—	—	—	—	—	54	25	—	—	19	60
	C		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	D		—	—	—	—	—	6	57	33	—	—	14	67	—	—	23	33	33	7	52	10
28	A		100	100	100	100	27	—	—	NP	33	50	—	—	15	—	—	NP	17	17	—	NP
	B		—	—	—	—	18	85	86	NP	67	—	—	100	77	25	57	NP	16	33	50	NP
	C		—	—	—	—	—	—	—	NP	—	—	—	—	—	—	—	NP	—	—	—	NP
	D		—	—	—	—	55	15	14	NP	—	50	100	—	8	75	43	NP	67	50	50	NP
42	A		100	100	100	NP	21	59	91	100	10	14	100	NP	24	22	100	NP	23	43	100	100
	B		—	—	—	NP	16	6	9	—	50	43	—	NP	7	—	—	NP	23	43	—	—
	C		—	—	—	NP	17	6	—	—	15	—	—	NP	28	—	—	NP	16	—	—	—
	D		—	—	—	NP	46	29	—	—	25	43	—	NP	41	78	—	NP	38	14	—	—
56	A		NP	NP	NP	NP	67	100	100	100	33	100	100	100	29	100	100	100	57	100	100	100
	B		NP	NP	NP	NP	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	C		NP	NP	NP	NP	—	—	—	—	33	—	—	—	14	—	—	—	14	—	—	—
	D		NP	NP	NP	NP	33	—	—	—	34	—	—	—	57	—	—	—	28	—	—	—

Days after second spray	Types of response	Stage of flower development*	Treatments: 25 ppm								50 ppm								100 ppm							
			1 spray				2 sprays				1 spray				2 sprays				1 spray				2 sprays			
			I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
14	A		100	67	60	100	100	100	90	33	80	92	20	60	75	64	69	NP	100	73	42	100	75	100	61	100
	B		—	5	30	—	—	—	—	67	—	—	20	—	—	29	12	NP	—	—	25	—	—	—	31	—
	C		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	NP	—	—	—	—	—	—	8	—
	D		—	28	10	—	—	—	10	—	20	8	60	40	25	7	19	NP	—	27	33	—	25	—	—	—
28	A		57	—	14	NP	29	33	12	NP	17	17	—	NP	—	25	33	NP	18	—	NP	NP	17	—	67	NP
	B		29	—	72	NP	57	67	88	NP	83	83	100	NP	—	25	—	NP	82	33	NP	NP	—	100	33	NP
	C		—	—	—	NP	—	—	—	NP	—	—	—	NP	—	—	—	NP	—	—	NP	NP	—	—	—	NP
	D		14	100	14	NP	14	—	—	NP	—	—	—	NP	100	50	67	NP	—	67	NP	NP	83	—	—	NP
42	A		9	12	33	100	—	—	NP	NP	7	22	80	NP	—	—	NP	NP	23	25	100	NP	—	—	NP	NP
	B		41	23	67	—	62	91	NP	NP	53	67	—	NP	83	100	NP	NP	31	67	—	NP	100	100	NP	NP
	C		27	24	—	—	19	—	NP	NP	13	—	—	NP	—	—	NP	NP	—	—	—	NP	—	—	NP	NP
	D		23	41	—	—	19	9	NP	NP	27	11	20	NP	17	—	NP	NP	46	8	—	NP	—	—	NP	NP
56	A		50	100	100	100	100	100	100	100	43	50	80	100	Dried up				28	100	100	100	Dried up			
	B		—	—	—	—	—	—	—	—	—	—	—	—	,,	,,	,,	,,	—	—	—	—	,,	,,	,,	,,
	C		—	—	—	—	—	—	—	—	14	13	—	—	,,	,,	,,	,,	29	—	—	—	,,	,,	,,	,,
	D		50	—	—	—	—	—	—	—	43	37	20	—	,,	,,	,,	,,	43	—	—	—	,,	,,	,,	,,

*For details *see* text; NP, Not present; —, No response; A, Normal pistil; B, Pistil absent or poorly developed; C, Increased number of carpels, double ovary etc.; D, Miscellaneous (includes abnormalities such as: free carpels, basally fused but apically free carpels with exposed ovules; pistils of different sizes; styles varying in number; fusion of styles with a well-developed ovary)

These were with or without ovules. The production of twin or triple fruits was of low frequency and was observed when the plants had reached the end of flowering.

Differentiation of ovules from the base of the filament was also rarely observed in treated plants. Although this condition is sporadically noted in nature (Meyer 1966), there had been no previous records to the best of our knowledge of such induction by growth regulators.

Morphactins are known to modify flower sex expression: female flowers are produced in male plants of *Cannabis sativa* (Mohan Ram & Jaiswal 1971); male sex is partially or fully suppressed in bisexual flowers of *Nicotiana*, *Antirrhinum* (Sankhla 1969, 1970), *Capsicum* (Jayakaran 1972); *Calendula officinalis* (Mehta & Mohan Ram 1979); a shift towards maleness is observed in *Luffa acutangula* (Bose & Nitsch 1970, Krishnamoorty 1971); and female flowers are produced as a result of morphactin treatment in *Cucumis* (Robinson et al. 1971) and some other members of the Cucurbitaceae (*see* Merck Technical Data Sheet, 1965). Bojan et al. (1980) have recently reported that in *Acalypha indica* chlorflurenol suppresses the production of female flowers.

With this background in view, the possible role of chlorflurenol on the modification of flower development in linseed was examined. The results recorded at regular intervals over a period of 8 weeks were varied and perplexing.

Generally the stamens were less affected in the first 2 weeks after the second spray as compared to the pistil. Nevertheless, subsequently both stamens and pistil became susceptible to treatment effects. The anthers became transformed and the pistil showed poor development. Approximately 6 weeks after treatment, the stamens as well as pistil were suppressed. The flowers formed later bore pistils which showed not only reversion to normal condition, but also increased number of carpels and supernumerary ovules. During this period the stamens continued to be absent or poorly developed in flower buds of stages I and II. Thus male sterility occurred only for a brief period. At stages III and IV both stamens and pistils looked normal.

Thus chlorflurenol suppresses as well as promotes the differentiation of both the sex organs and the effects appear to be related to time after application rather than dosage. For instance it was noted that male sterility accompanied by female fertility, could be obtained only 42 days after the second spray for a very brief period. Otherwise chlorflurenol affected organs of both the sexes. The statement of Schneider (1972) that morphactin suppresses the male sex in bisexual flower has to be accepted with caution. Also his generalization (1970) that peripheral organs of a flower such as petals and stamens are more susceptible to treatment than the centrally located pistils is not supported by the present findings.

One important outcome of the present work is the recognition of the need to examine the effects over a prolonged period instead of making hasty observations which could be misleading. Also, any conclusion must be based on data collected from a large sample of flower buds at different stages of development.

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