Summary
The rapeseed-mustard crops are gaining wide acceptance among the farmers mainly because of their adaptability for both irrigated and rainfed areas, suitability as sole and mixed cropping; higher return with low inputs and low water requirement. Oil is a rich source of energy, which contains less saturated fatty acids than groundnut and coconut. Rapeseed-mustard oil is considered to be the ideal input for pickle industries and consumed by millions who cannot afford other oils, which are considered to be safer for human health. Since there is a lot of gap between the yield potential and the present actual yields, these important oilseed crops therefore need special attention.

Frost and aphids attack are the main constraint for the low productivity. Realising the importance of this crop, it was felt germane to determine some of the major components of integrated pest management so as to evolve effective strategy against economically important insect-pests in mustard ecosystem. The effect of sowing period, screening of different cultivars/germplasms for aphid tolerance, efficacy of insecticides to the mustard aphid, *Lipaphis erysimi* (Kaltenbach) vis-à-vis their impact on dynamics of the potential predators (*Coccinella septempunctata* L. and *Ischiodon scutellaris* Fabricius), predation potential of these predators and their life-tables under controlled and natural conditions were extensively studied.

The comparative data obtained for insect-pest succession showed significant difference in the population build-up of *L. erysimi* on cv. Varuna on different sowing dates. The maximum population of 150.50, 428 and 420.95/10 cm terminal shoot/plant was recorded in the fourth week of January at first sowing, second week of February at second and fourth week of February at third sowing during 2000-01. The corresponding range of temperature and relative humidity during varied sowing dates were recorded as 8.2-21°C and 44-75% RH; 8.8-23.7°C, 44% to 75% RH; 10.5-24.6°C, and 38 to 83% RH. Favourable temperature and humidity was a clear indication of high population during second and third sowing. The earlier planted crop exhibited better growth due to stored moisture with minimum incidence of aphid than the crop planted at later dates. The population of mustard sawfly, *Athalia lugens proxima* was noticed at the seedling stage of the crop. The population count of this species reached maximum (0.32/plant) during second and third week of November at first sowing when temperature and humidity were in the range of 27.7-13.4°C, 42-5%. However, at second and third sowing, the higher population of 0.08, and 0.04/plant
was encountered in the first week, and second and third week of December, respectively. The corresponding range of temperature and relative humidity were 6-23.9°C, 6.8-23.2°C, and 35-82, 38-86% RH. The leaf miner (C. horticola) commenced its attack from third week of December and continued till fourth week of February showing highest population of 1.58 mines/plant in the last week of first sowing when the temperature and relative humidity ranged between 10.5-24.6°C and 38-83%. In second and third sowings, the infestation further intensified and reached to a maximum of 6.64 and 5.78 mines/plant in the first week of March. During this period, the favourable temperature and relative humidity were 10-26.7°C and 30-78%, respectively. The activity of painted bug was recorded at the seedling stage during first sowing at a temperature range of 14-26.6°C and 51.7-92.7% RH, the high population (0.16/plant) was witnessed in the third week of November, during second and third sowing. In the second and third sowings, this species appeared at seedling stage as well as crop maturity. The maximum population of 0.04/plant was recorded at both stages. As far as larvae of cabbage butterfly (P. brassicae) were concerned, in the first and second sowings, two attacks were witnessed, first at seedling and thereafter at pod formation stage. At seedling stage of first sowing, the numerical strength of larvae was low (0.32/plant) as compared to high (0.64) at pod formation stage in the first week of February at a temperature and RH range of 8.6-22.4°C and 30-79%. Nonetheless, its maximal strength to the tune of 0.64 (third week of December, 8.9-23.7°C and 39-88% RH), and 4.00/plant (fourth week of February, 10.5-24.6°C and 38-83%) were recorded in the second and third sowings, respectively.

Syrphids exhibited peak activity in the second and fourth week of February (temperature ranged between 10.6-24.7°C and RH from 40-82%) during first and second sowing and fourth week of February as well as first week of March in the third sowing (10.6-25.6°C and RH 34-80.5%), respectively. Their corresponding population was 2.50, 1.16, and 2.54-maggots/10 cm terminal shoot/plant. While the coccinellids attained the maximum count of 3.24 (fourth week of February), 4.32 (second week of February) and 3.52/plant (second week of March) during first, second and third sowings, respectively. The corresponding range of temperature and relative humidity were 10.5-24.6°C and 38-83%, 8.8-23.7°C and 47-80%, 15.2-20.5°C and 34-65%.
Perusal of data for the population dynamics of various pests for the year 2001-02, showed that, the mustard aphid revealed a high count of 17.80/10 cm terminal shoot/plant during first week of February at the first sowing when temperature and RH ranged between 7.8-19.8°C and 54-83%. However, the populations increased manifold (105.16 and 127.44/10 cm terminal shoot/plant) during third week of February at second and third sowings. During this period the range of temperature and RH were 12.7-26.2°C and 38-75%. Mustard sawfly was however, recorded at the seedling stage. In the first sowing at 10.2-26.6°C and 26-76% its highest population (0.24/plant) was noticed in third week of November followed by 0.16 in third week of December and 0.12 in the first week of January) during second and third sowings, respectively. The crop was infested with larvae of *P. brassicae* from the first to fourth week of January during first sowing, showing highest population counts of 4.52/plant in the third week of January. The temperature range between 7.9-18.2°C and RH 52-83% were recorded during this period. The population of this species further intensified towards maturity during second and third sowings. The corresponding population counts were 4.12/plant (fourth week of February) and 16.36/plant (second week of March). The leaf miner appeared from the third week of January, at first and second sowings followed by fifth week of January in third sowing. Their corresponding peak populations were 0.92, 5.48, and 3.72 mines/plant, respectively. The painted bug was recorded at negligible counts during seedling stage of all the sowing periods. They attained maximum strength of 0.16 (third week of November), 0.08 (fourth week of November) and 0.04/plant (second week of December) in first, second and third sowings, respectively. The corresponding temperature and relative humidity of the observational periods were 10.2-26.6°C and 26-76%, 9.8-24.7°C and 29-77%, and 10.8-21.6°C and 50-88%.

The activity of the syrphids was recorded from January onwards. Their maximum population synchronised with the highest numbers of aphids. The peak population of 1.32/10 cm terminal shoot/plant, was found in the second week of February during first sowing at a temperature of 9.5-20.4°C and RH 48-90% followed by 0.36 on fourth week of February when temperature and RH ranged between 12.8-22.2°C and 55-82%, respectively. Similarly, coccinellids were found to be at a high of 1.72, 2.16 and 2.32/plant in the first week of March during first and second sowing and fourth week of February at third sowing, respectively. The respective range of
temperature and RH of above observational period varied from 13-26°C and 32-72% RH, 12.8-22.2°C and 55-82% RH.

The mean aphid infestation index revealed that most of the cultivars/germplasms were susceptible to aphid attack (MAII>2). The germplasms, RH-30, Bio-772, RH-8113, and Sej-2 were found to be relatively safe (MAII<2), and hence were adjudged suitable for cultivation.

To determine the effect of various abiotic (maximum and minimum temperature, maximum and minimum relative humidity, evaporation, rainfall and wind velocity) as well as biotic (syrphid and coccinellid) factors on the population build-up of mustard aphid during different sowing dates, the data was subjected to multiple correlation regression analysis. It was inferred that high degree of positive correlation existed between the different variables and the mustard aphid. On further exploration it was discerned that syrphids were the single factor influencing the mustard aphid population in first and third sowings of 2000-01 and first and second sowings of 2001-02. Nonetheless, coccinellids put the pressure on the aphid multiplication during second sowing of 2000-01. However, rainfall was the limiting factor during third sowing of 2001-02.

When the relative performance of most widely used insecticides by the farming community of Aligarh and its adjoining areas for the control of Lipaphis the in mustard ecosystem was evaluated, it was found that phosphamidon (0.03%), oxydemeton-methyl (0.03%) and chlorpyriphos (0.05%) were statistically superior to others. Different treatments also reflected differential response on net profit and cost: benefit ratio. The highest monetary return of Rs. 18885.05/ha was obtained from the crop treated with phosphamidon (0.03%) while the lowest (Rs. 7279.673/ha) was from neemarin (1:100 dilution). Similar was the trend with respect to cost: benefit ratio (CBR), the maximum CBR of 1:71.94 was achieved from the phosphamidon (0.03%) treated crop followed by 1:22.95 (malathion and dimethoate), 1:16.62 (endosulfan), 1:16.40 (oxydemeton-methyl), 1:9.72 (chlorpyriphos) and 1:6.08 (neemarin).

All the insecticide treatments showed their impact on the population dynamics of C. septempunctata and I. scutellaris. Neemarin (1:100 dilution) and endosulfan (0.05%) were found safe against predators. Phosphamidon (0.03%) followed by
oxydemeton-methyl (0.03%) were the most toxic, whereas others showing intermediate effect.

When the predation potential of *C. septempunctata* and *I. scutellaris* was ascertained, syrphids exerted maximum and minimum feeding potential at fluctuating temperatures of 18/24±1°C and 24/28±1°C, respectively in both the generations. Similarly, *C. septempunctata* consumed more aphids at a constant temperature of 18±1°C, while fluctuating temperature of 24/28±1°C proved to be the least favourable.

While constructing the age specific life-tables at varying temperatures (18, 24, 28, 18/24, 18/28, 24/28±1°C) coupled with 70±5% relative humidity each, it was evident that *C. septempunctata* needed a maximum of 68 days to complete its cycle at 18±1°C and a minimum of 40 days at 28±1°C. In contrast, *I. scutellaris* required longest duration of 52 days at 18±1°C, while, the shortest time period of 29 days was required at 28±1°C and 24/28±1°C. Life expectancy (ex) showed slow and steady decline throughout the generation at all the temperatures for both species. A marginal increase in ex was however, recorded at certain age intervals of the larvae.

A cursory glance over comparative stage specific life-table at different developmental stages and generations of *C. septempunctata* at three constant and fluctuating temperatures revealed that the apparent mortality and mortality survivor ratio were of high order (15%) at the egg stage at 28±1°C (gen. II) and 0.13 at prepupal stage at 18±1°C (gen. II), 24/28±1°C (gen. II) whereas for *I. scutellaris* the values were 27.14% and 0.37 at pupal stage at 24±1°C. The total generation mortality 'K' recorded a high of 0.2147 at 24/28±1°C for *C. septempunctata* and 0.2924 at 18/24±1°C (gen. I) for *I. scutellaris*, in contrast to low of 0.1427 at 18±1°C (gen. I) and 18/24±1°C (gen. II) and 0.0809 at 18/24±1°C (gen. I) for *C. septempunctata* and *I. scutellaris*, respectively. Thus it was inferred that temperatures of 18±1°C and 18/24±1°C were favourable for the overall development of *C. septempunctata* while 18/24±1°C for *I. scutellaris*.

It was inferred from the life and fertility-tables for *C. septempunctata* that the ovipositional period ranged between 9 to 21 days at 28±1°C (gen. I, II) and 18±1°C (gen. II), respectively. Maximum potential fecundity (211.65 eggs/female) was obtained at 18±1°C (gen. I) as compared to minimum (74.35 eggs/female) at 24/28±1°C (gen. II). The net reproductive rate happened to be a high of 62.96 at
18±1°C (gen. II) against a low of 16.73 at 28±1°C (gen. I). The longest mean length of
generation (55.70 days) was obtained at 18±1°C (gen. II), while the shortest (34.41
days) at 28±1°C (gen. II). Correspondingly, accurate intrinsic rate of increase was of
high order (0.096720) at 18/24±1°C and low (0.075091) at 18±1°C in the second
generation. Doubling time exhibited pronounced variation wherein the longest
duration of 9.23 days was observed at 18±1°C (gen. II) and shortest 7.17 days at
18/24°C (gen. II). It was found that maximum annual rate of increase to the tune of
2E+015 was at 24±1°C, 18/24°C while the minimum, 8E+011 at 18±1°C during
second generation.

As far as I. scutellaris was concerned, the maximum interlude for total natality
of 11 days was at 18°C (gen. I) contrary to the minimum of 6 days at 24°C, 18/28°C
and 24/28±1°C (gen. II). The highest input (30.98%) of egg laying was on 28.5 day at
24/28°C (gen. I) and the lowest (12.38%) on 35.5 day at 18±1°C (gen. I). Potential
fecundity and net reproductive rate exhibited maximum value of 21 eggs/female and
7.15 at 18°C (gen. I) against the minimum of 1.58 followed by 9.20 at 24/28±1°C
during first and second generations, respectively. The longest mean length of
generation (38.08 days) was recorded at 18±1°C and shortest (25.38 days) at 28±1°C.
The intrinsic, finite, and annual rate of increase encountered superior values of
0.05557, 1.06, 7E+08 at 18/24°C (gen. II) as compared to inferior of 0.017876, 1.02
(24°C gen. I), 7E+002 at 24/28°C, gen. I, respectively. The longest doubling time
(38.78 days) was at 24/28°C (gen. II) while the shortest (12.44 days) happened to be
at 18/24°C (gen. II). Thus from these parameters it could be inferred the 18°C and
18/24°C were favourable temperatures for multiplication of C. septempunctata and
18/24°C for I. scutellaris.

The data collected during field studies for two successive years on age specific
survivorship (lx) of C. septempunctata and I. scutellaris revealed that the survivorship
decayed at a faster rate for the first 2-4 days of development. This decline coincided
with mortality of eggs and juvenile larvae. However, intermittent stability in lx was
encountered throughout the life period of both species and during both the years. The
life expectancy (ex) declined gradually with the advancement of insect age. However,
negligible increase in ex was recorded at certain age intervals. From stage specific
life-table, it was concluded that abiotic factors had a direct bearing on the population
build-up of *C. septempunctata* (K=0.2076) whereas abiotic and biotic factors (hyperparasitoids: tachinid fly and *Diplazon orientalis*) played vital role (K=0.4815) against *I. scutellaris*.

While constructing fecundity-table, it was found that *C. septempunctata* recorded higher potential fecundity (155.85 eggs) and doubling time (8.34 days) during 2001. Conversely, significant values for net reproductive rate (51.10) mean length of generation (43.61), intrinsic rate of increase (0.090739) and annual rate of increase (2E+014) were recorded during 2002. For *I. scutellaris* the trend was similar for both the years, wherein the maximum potential fecundity (16.60) was recorded in the first generation (2001) while the net reproductive rate, intrinsic rate of increase and annual rate of increase exhibited higher values of 2.12, 0.021900, 3E+003, respectively in the second generation.

**FUTURE THRUST AREAS**

The rapeseed and mustard are gaining popularity among the farmers because of their adaptability for both irrigated and rainfed areas. However, fall in production during the last four years from 6.66 Mt in 1996-97 to 4.21 Mt in 2000-01 and the area under production from 7.04 M ha in 1997-98 to 4.83 M ha in 2001-02 have indicated that the farmers are loosing interest in these crops or shifting to another alternate crops. This issue needs immediate attention and to be dealt with right earnest.

The mustard aphid, *L. erysimi* (Kaltenbach), is a proven menace to the mustard crop and other cruciferous plants in India. This species survives on off-season herbaceous cruciferous plants in and around the crop fields and makes the seasonal colonization on mustard, cauliflower, cabbage, and other cruciferous crops. Chemical control is the effective means of saving the crop from the recurring incidence of this pest species. But hazardous effects of chemical control are well known. Integrated control strategy is gradually replacing the chemical control methods. Use of biocontrol agents in suitable combination with selective insecticides will be effective and non-hazardous means of achieving pest control. The parasitoid, *Diaeretiella rapae* (Mc’Intosh) and predators viz., *Coccinella septempunctata* and different syrphid species, have been evaluated to be the effective biocontrol agents of *L. erysimi*. They show strong preference for *L. erysimi* in Indian conditions. Their use is likely to be effective in mustard crop selectively treated with insecticides. The real damage of
the mustard crop is at the later part of the vegetative phase. At this stage effective biocontrol agents are generally in the process of building up of their populations. Therefore, certain vision coupled with a strategy can prove a milestone to overcome the hazards of chemicals on the one hand and cumulative implementation of cultural, physical, chemical and biological methods on the other. The aspects to be pondered over include, manipulating the planting dates, providing the farmers with mustard tolerant and early maturing varieties, introducing more natural enemies by augmenting them in captivity in a mass rearing programme and releasing them in the field, making better use of resident natural enemies, use of eco-friendly insecticides, strictly at the recommended doses. mass scale interaction with the farmers so that they get acquainted with the techniques and providing them the agents for release in fields when required.