RESULTS
In the present investigations, the cytological studies were carried out in eleven species of grasshoppers from Himachal Pradesh. Karyological data belonging to different species are presented in Table 2.

Out of eleven species studied cytologically, nine species belong to family Acrididae and two species belong to family Pyrgomorphidae. For the determination of the karyotype in different species, gonial metaphases in case of males and somatic metaphases in case of females were studied. Meiotic mechanisms in these species were studied only in males.

The species belonging to family Acrididae have 2n=23 in males and 2n=24 in females and that of family Pyrgomorphidae have 2n=19 in males and 2n=20 in females with slight variations in their karyotypes. The karyotypes and meiotic mechanisms of the grasshopper species are given below.

**Family Acrididae**

**Subfamily Oxyinae**

*Oxya hyla hyla* Serv.

The individuals of *Oxya hyla hyla* were collected from the rice fields during the months of August to November (Table 1). These insects were brownish in colour from upper side and greenish from lower side. A brown coloured stripe is present on the dorsal surface of the body. The individuals of *Oxya hyla hyla* were found in groups of 5 to 10.

2n number is 23 in males (Fig. 1a) and 24 in females (Fig. 1b) of *Oxya hyla hyla*. All the chromosomes are acrocentric (Fig. 1a,b). The chromosomes are categorized into three categories based on their relative length data. Those having relative lengths above 10% are grouped as large (L), between 5 and 10% as medium (M) and less than 5% as short (S).

Male karyotype of *Oxya hyla hyla* consists of eleven pairs of autosomes and a single X chromosome and a single supernumerary chromosomes. Out of these,
three pairs are long (L₁-L₃), six pair are of medium size (M₄-M₉) and two pairs are of short chromosomes (S₁₀-S₁₁) (Fig. 1c). Relative length of the largest chromosome pair is 17.133 ± 0.11SE and that of the shortest chromosome pair is 2.727 ± 0.07SE. X chromosome is also of larger size but is not the largest in the complement having relative length as 11.217 ± 0.20 SE (Fig. 30a, Table 2). X chromosome shows positive heteropycnosis.

Female karyotype in somatic metaphase plates show 2n=22(XX), with all acrocentric chromosome (Fig. 1b). There are three pairs of long, six pairs of medium and two pairs of short antosomes and a pair of X chromosomes (Fig. 1b).

Meiotic stages: Meiotic stages in the male germinal cells are as follows:

**Zygotene:** During this stage, the condensation of the chromosomes starts. The bivalents are not clearly visible as these appear as a coiled mass of the chromosomes (Fig. 2a).

**Pachytene:** During pachytene the homologues get coiled to each other. The bivalents get thicker and shorter at this stage. Highly condensed X chromosome is distinctly visible and shows heteropycnosis (Fig. 2b).

**Diplotene:** The chromosomes get reduced in size because of the higher degree of condensation. During this stage, the homologues which have synapsed earlier, start pulling apart from each other and move apart except at few points where they are held together by chiasmata (Figs. 2c, d, e). X chromosome appears highly stained during diplotene.

**Diakinesis:** In this stage, eleven bivalents and one X chromosome are clearly visible (Fig. 2f). X chromosome is slightly thickened as compared to autosomes. Autosomes exhibit various configurations such as rods, crosses, double crosses, rings and stars (Fig. 2f).

**Prometaphase I:** The chromosomes reach their maximum contractions, 11 bivalents and a single X chromosome are clearly visible (Fig. 2g).
Metaphase I: Metaphase I, shows the karyotype clearly with 11 autosomal bivalents in the form of rods, crosses and rings and an univalent which is X chromosome (Fig. 2h).

Metaphase II: The chromatids of each chromosome are widely separated and start moving to different poles (Fig. 2i).

Anaphase II: The chromatids move apart from each other and reach at different poles (Fig. 2j).

Chiasma Frequency:

Chiasma frequency is calculated in Metaphase I, diplotene and diakinesis stages collectively. The mean chiasma frequency is found to be 8.5 ± 1.26 (Table 3). Terminalization coefficient is also calculated and found to be 0.68 (Table 3).

Chromosomal anomalies: Chromosomal anomalies in the natural population of Oxya hyla hyla were observed in the form of polyploid cells (Fig. 3a, b) and anaphase bridge (Fig. 3c).

Oxya velox Fabr.

Individuals of Oxya velox Fabr. were collected from the rice fields during the months of September (Table 1). The individuals were greenish brown in colour with brown eyes. Legs are slender. This species is gregarious in nature.

The diploid chromosome number (2n) in this species is 23 in males (Fig. 4a) and 24 in females (Fig. 4b). All the chromosomes are acrocentric (Figs. 4a, b). Male karyotype of this species from the gonial metaphase plates shows eleven pairs of autosomes and a single X chromosome. There are three pairs of long (L₁ - L₃), six pairs of medium (M₄-M₉) and two pairs of short (S₁₀-S₁₁) chromosomes (Fig. 4c). Relative length of the longest chromosomal pair is 15.718 ±0.10 SE and that of the shortest chromosomal pair is 3.098 ± 0.08 SE. The relative length of X chromosome is 12.235 ± 0.08 SE (Fig. 30b, Table 2).
Female karyotype reveals the presence of 24 acrocentric chromosomes (Fig. 4b). Autosomes have three pairs of long, six pairs of medium and two pairs of short chromosomes (Fig. 4b). The X chromosomes pair is the largest of the complement.

**Meiotic stages**

Following meiotic stages were observed in the male meiosis of *Oxya velox*. During zygotene (Fig. 5a), the chromosomes are not clearly visible, but they appear in the form of dense chromatin material. In diplotene, the bivalents appear considerably reduced in size. The synapsed homologues start pulling apart from each other. Bivalents move apart but are held together at chiasmata (Fig. 5b). Highly condensed eleven bivalents and one X chromosomes are distinctly visible in diakinetic stage (Fig. 5c). X chromosome is slightly thickened than autosomes. Autosomes show various configurations such as rods, crosses, rings and stars etc.

During metaphase I, bivalents are highly condensed. Out of 12 elements, 11 are autosomal bivalents occurring in the form of rods and rings. The remaining element is a single unpaired X chromosome (Fig. 5d). At anaphase I, synapsed homologues move apart from each other after condensation and terminalization and reach at different poles (Fig. 5e).

During metaphase II (Fig. 5f) chromatids become wide apart from each other and they tend to lie on equatorial line. Chromatids undergo separation and start moving to opposite poles during anaphase II (Fig. 5g).

**Chiasma Frequency**

Chiasma frequency in metaphase I, diplotene and diakinesis stages collectively were found to be $5.8 \pm 1.9$ SE and terminalization coefficient was found be 0.65 in *Oxya velox* (Table 2).
Chromosomal anomalies

Only uncondensed form of metaphase II were observed (Fig. 6).

Subfamily Catantopinae

*Catantops pinguis innotabilis* Stal.

The individuals of *catantops pinguis innotabilis* were collected from the grass fields during the month of December (Table 1). These are light to reddish brown in colour, having stout body with thoracic region less darker than rest of the body. Undersurface of the body and the legs is pale and abdomen has a short narrow dorsal stripe. Black spots are present on the legs of these individuals, hind tibiae and tarsi are red with black tipped spines.

Diploid chromosome number in this species is 23 in males (Fig. 7a) and 24 in females (Fig. 7b). All the chromosomes including the X chromosome are acrocentric (Figs. 7a, 7b). Karyotype of males from the spermatogonial metaphase plates reveals that 23 acrocentric chromosomes can be grouped into long, medium and short categories, based on relative lengths data. There are four pairs of long (L₁-L₄), five pairs of medium sized chromosomes (M₅-M₉) and two pairs of short chromosomes (S₁₀-S₁₁) (Fig. 7c). X chromosome is highly heteropycnotic and can be easily identified in the complement. The relative length of the longest chromosome pair in the complement is $12.486 \pm 0.24$ SE and that of the shortest pair is $3.725 \pm 0.11$ SE and the relative length of the X chromosome is $5.608 \pm 0.13$ SE (Table 2). The length of the X chromosome is inbetween pair M₉ and S₁₀ autosomal pairs (Fig. 30 c).

The female somatic metaphase plates show that 2n=24 and the chromosomes are arranged in three groups i.e. there are four pairs of large chromosomes, five pairs of medium and two pairs of short autosomes and a pair of X chromosomes (Fig. 7b).
Meiotic stages

In pachytene stage (Fig. 8a), the homologues are coiled around each other. The bivalents are more thick and short at this stage. In the bouquet stage of pachytene, highly condensed chromosomes are arranged in a group (Fig. 8b). Chromosomes are more condensed during diplotene stage and the homologues are held together at chiasmata (Fig. 8c). In diakinesis, chromosome complements are clearly visible, having eleven bivalents and a darkly stained X chromosome. Autosomes exhibit various configurations such as rods, crosses, stars and rings etc. (Fig. 8d). In Metaphase I (Fig. 8e), these 12 elements (11 autosomal elements + X chromosome) can be easily counted. Homologues start moving apart during anaphase I (Fig. 8f). In prometaphase II (Fig. 8g), and metaphase II (Fig. 8h) the chromatids show a wide separation and these get arranged on the equatorial line.

Chiasma Frequency

Chiasma frequency recorded during diakinesis and metaphase I stages of this species is 7.4 ± 1.18 SE and the terminalization coefficient is found to be 0.67 (Table 3).

Sub family Euprocnemidinae

*Choroedocus capensis* Thunb.

The individuals of *Choroedocus capensis* Thunb. were collected from the rice fields in the month of October (Table 1). The individuals were brownish in colour with spotted legs. A black line was present on the head region. Eyes were light brown in colour. These individuals occurred in the groups of 3-4 individuals.

The diploid chromosome number is 23 in the case of males (Fig. 9a) and 24 in case of females (Fig. 9b). All the chromosomes including X chromosome are acrocentric (Fig. 9a, b). Karyotype in males has eleven pairs of autosomes and a single X chromosome which is highly stained due to positive heteropycnosis. The
chromosomes are divided into three categories i.e. three pairs of long chromosomes (L₁-L₃), five pairs of medium chromosomes (M₄-M₉) and three pairs of short chromosomes (S₁₀-S₁₁) (Fig. 9c). The relative length of the longest chromosome pair is 13.211± 0.38 SE and that of the shortest chromosome pair is 4.643± 0.08 SE. Relative length of X chromosome is 9.45± 0.08 SE which is inbetween the fourth and fifth (M₄-M₅) chromosomal pair (Fig. 30d, Table 2). Female karyotype from somatic metaphase plates shows the presence of 24 acrocentric chromosome (Fig. 9b). Autosomes have three pairs of long, five pairs of medium and three pairs of short chromosomes.

Meiotic Stages

In zygotene stage of the meiosis, the bivalents form a coiled mass and are not clearly visible (Fig. 10a). Chromosomes are very condensed in diplotene (Fig. 10b) and in later stage, the homologues repel each other and get separated except at chiasmata. During diakinesis, eleven bivalents and an X chromosome are clearly visible. X chromosome is slightly thickend than autosomes. Autosomes exhibit various configurations such as rods, crosses, rings and stars (Fig. 10c).

Chromosomes reach their maximum contraction during prometaphase I (Fig. 10d). Metaphase I configuration exhibits twelve elements (11 bivalents and an upaired X chromosome) (Fig. 10e). Homologues which had synapsed, condensed and their chiasmata terminalized, now start moving apart from each other towards the respective poles, during early anaphase I (Fig. 10f).

Chiasma Frequency

Chiasma frequency in this species was calculated in metaphase I, diplotene and diakinesis stages collectively. The mean chiasma frequency was found to be 9.1± 1.59 SE and the terminalization coefficient was also calculated which is 0.60 (Table 3).
Individuals of *Euprepocnemis alacris* were collected from rice and grass fields during the period from October and December (Table 1). The individuals were yellowish brown in colour. There was a black triangular patch on the thoracic region of each individual. Stripped dark brown legs have red-ends. Individuals were found in groups.

The diploid chromosome number (2n) is 23 in males (Fig. 11a) and 24 in females (Fig. 11b). All the chromosomes are acrocentric in nature (Fig. 11a, b). Male karyotype of the grass field and rice field collected individuals resembles in every respect. It reveals that there are four pairs of large (L1-L4), four pairs of medium (M5-M8) and three pairs of short chromosomes (S9-S11) (Fig. 11c). The relative length of X chromosomes is inbetween M5 and M6 (Fig 30e). Relative lengths of the longest, shortest and the X chromosomes are 15.070± 0.08 SE, 3.698± 0.12 SE, 8.635± 0.11 SE respectively (Table 2).

Female karyotype of the grass field and rice field collected individual of *E. alacris* reveals that it comprises of four pairs of long, four pairs of medium, three pairs of short autosomes and a pair of X chromosomes (Fig. 11 b).

**Meiotic stages**

During zygotene, the highly condensed chromosomes form a coiled mass (Fig. 12a). The bivalents are not clearly visible, condensation of the bivalents is more, which appear thicker and coiled during pachytene (Fig. 12b). The chromosomes get shortened due to higher degree of condensation. These homologues start moving apart and get separated in diplotene except chiasmata (Fig. 12c). X chromosome is deeply stained in diplotene. During diakinesis, various configuration are exhibited by autosomes. Eleven bivalents and an X chromosome are clearly visible during this stage (Fig. 12d).
Metaphase I stage exhibits 12 elements, 11 of which are autosomes in the form of rods, rings and crosses and 12th is an univalent X chromosome (Fig. 12e). During metaphase II (12 f) the chromatids move wide apart and they tend to lie on equatorial line. In anaphase II (Fig. 12g) chromatids of each chromosome separate and they start moving to opposite poles.

**Chiasma Frequency**

Mean chiasma frequency in this species was found to be $7.6 \pm 2.06$ SE and terminalization coefficient was found to be 0.64 (Table 3).

**Chromosomal anomalies**

Chromosome anomalies in the form of polyploid gonial metaphase (Fig. 13a) and laggard chromosome in telophase I (Fig. 13b) have been observed.

**Subfamily Hemiacridinae**

*Hieroglyphus nigrorepletus* Bol.

The individuals of *Hieroglyphus nigrorepletus* were collected from rice fields and were available from August to November (Table 1). These individuals were light green in colour, large in size with green coloured medium sized antennae, orange oblong eyes and head facing downwards with smooth pronotum having four black lines. These were generally found in solitary state but occasionally they occurred in groups also.

In this species, $2n=23$ in males (Fig. 14a) and $2n=24$ in females (Fig. 14b). All the chromosomes are acrocentric in nature (Fig. 14a, b). Male karyotype observed in gonial metaphase plates shows eleven pairs of autosomes and an X chromosomes. Autosomes are divided into three categories depending upon their relative lengths. There are three pairs of long chromosomes ($L_1-L_3$), seven pairs of medium chromosomes ($M_4-M_{10}$) and one pair of short chromosome ($S_{11}$)
Relative length of the longest chromosome pair is $15.319 \pm 0.07$ SE and that of the shortest chromosome pair is $3.379 \pm 0.10$ SE. Relative length of the X chromosome is $10.367 \pm 0.10$ SE (Fig. 30f, Table 2).

Somatic metaphases (Fig. 14b) of females revealed $2n=24$ having acrocentric chromosomes. There are three pairs of long, seven pairs of medium and one pair of short autosomes and a pair of X chromosome.

**Meiotic stages**

The chromosomes start condensing and appear indistinct in zygotene (Fig. 15a). The synapsed homologues start pulling apart from each other during diplotene and remain attached only at chiasmata (Fig. 15b). Chromosomes are clearly visible during diakinesis (Fig. 15c). Metaphase I configuration (Fig 15d) exhibit 12 elements, 11 of which are autosomal bivalents in the form of rods, crosses and rings and the remaining one is an unpaired X chromosome. During metaphase II, chromatids orientate towards opposite sides and then the chromosomes arrange themselves on the equatorial plate (Fig. 15e). During anaphase II, separated chromatids of the chromosomes reach at different poles (Fig. 15f).

**Chiasma frequency**

Chiasma frequency is $7.1 \pm 1.85$ SE and terminalization coefficient is 0.64 in this species (Table 3).

**Spathosternum prasiniferum Walk**

The individuals of *Spathosternum prasiniferum* were collected from the rice and grass fields from August to November (Table 1). These individuals were green in colour having a blackish or dark green stripes running behind the lower part of the eyes. Brown stripes were also present on the lateral sides of the body. The individuals were gregarious in habit.
In both the samples of this species, 2n=23 in male (Fig. 16a, 17a) and 24 in female (Fig. 16b, 17b). In the karyotype of males, out of 11 pairs of autosomes there are four pairs of long (L₁-L₄), six pairs of medium (M₅-M₁₀) and one pair of short (S₁₁) chromosomes (Fig. 16c, 17c). Relative lengths of longest and shortest chromosome pair and X chromosome are 13.217±0.13 SE, 3.871±0.07 SE, 12.792±0.09 (Fig 30, Table 2) respectively in case of rice field collected *Spathosternum prasiniferum*. Relative lengths of longest, shortest and the X chromosomes in case of grass field collected *Spathosternum prasiniferum* are 13.913±0.11 SE, 4.831±0.12SE, 4.052±0.19 SE (Fig. 30, Table 2) respectively. The main difference in these two population of *Spathosternum prasiniferum* is at the level of X chromosome which is longer in the complement of rice field collected population of *S. prasiniferum*, having relative length inbetween L₁ and L₂ autosomal pair (Fig 30g) and in the grass field collected population of *S. prasiniferum*, X chromosome is the shortest member of the complement (Fig. 30h).

Similarly in females 2n=24 (Figs. 16b, 17b) and karyotype of both the collection of *Spathosternum prasiniferum* reveal the presence of four long, six medium, one pair of short autosomes and a pair of X chromosomes (Fig. 16b, 17b).

**Meiotic stages**

Stages of meiosis observed in *Spathosternum prasiniferum* are as follows:

Zygotene (Fig. 18a), shows the undifferentiated chromosomal mass. Chromosomes are highly condensed in pachytene stage and the homologues are coiled around each other (Fig. 18b). During diplotene, the synapsed bivalents are much more shorter because of the high degree of condensation and they start moving apart from each other but remain attached at chiasmata (Fig. 18c). During diakinesis (Fig. 18d), bivalents and a single X chromosome are visible clearly. Autosomes are present in various configuration such as rods, rings crosses etc.
In metaphases I, 11 bivalents and one X chromosome are distinctly visible (Fig. 18e). In Anaphase I, the chromosomes along with their chromatids start moving apart towards their respective poles (Fig. 18f) and finally reach at the opposite poles in telophase I (Fig. 18g). In metaphase II (Fig. 18h), the chromatids move apart from each other and tend to be on the equatorial plane.

**Chiasma Frequency**

Chiasma frequency was found to be 9.1±3.14 SE (Table 3) in rice field population and 12.2±1.9 S.E in grass field population of *Spathosternum prasiniferum* (Table 2). The terminalization coefficients in both these collections were found to be 0.63 in rice field and 0.68 in grass field collection of *Spathosternum prasiniferum* (Table 3).

**Subfamily Oedipodinae**

*Acrotylus humbertianus* Sauss.

The individuals of this species were collected from grass fields and were available from October to December (Table 1). The individuals were light brown in colour. These have hyaline wings with light black spots and a blackish mark is present on the thorax. The individuals were found in the groups of two or three, here and there.

The diploid chromosome number (2n) is 23 in males (Fig. 19a) and 24 in females (Fig. 19b). All the chromosomes are acrocentric (Figs. 19a, 19b). Male karyotype was prepared from the spermatogonial metaphases plates. Based on their lengths, the autosomes are divided into three categories. There are three pairs of long chromosomes (L₁-L₃), five pairs of medium chromosomes (M₄-M₈) and three pairs of short chromosomes (S₉-S₁₁) (Fig. 19c). X chromosome is the largest member of the complement (Fig. 30I, Table 2). Relative length of the X...
chromosome is 12.949±0.10 SE. Relative lengths of the longest autosomal pair is 12.547±0.07 SE and that of the shortest pair is 3.279±0.14 SE (Table 2).

Somatic metaphases of females reveal that 2n=24 (Fig. 19b) and all chromosomes are acrocentric and there are three pairs of long, five pairs of medium, three pairs of short autosomes and a pair of X chromosomes (Fig. 19b).

Meiotic stages

Various stages of meiosis observed in this species are as follows:

During zygotene stage (Fig. 20a), there is condensation of the chromosomes and the bivalents are not clearly visible, but appear as a coiled mass of the chromosomes. In pachytene (Fig. 20b) and bouquet stage of pachytene (Fig. 20c), the homologues are highly coiled around each other. In diplotene (Fig 20d), the chromosomes get very much shortened due to higher degree of the condensation. Homologues appear separating from each other except at chiasmata. X chromosome appears deeply stained in this stage. During diakinesis (Fig. 20e) bivalents and X chromosome are clearly visible. In anaphase I (Fig 20f), chromosomes move towards opposite poles after having their chiasmata terminalized and the chromatids separated. In prometaphase II (Fig. 20g), chromosomes arrange themselves on equatorial plane with widely separating chromatids. In metaphase II (Fig 20h), the chromosomes are placed on the equator of the metaphases spindle in a circle. Chromatids show a wide separation and start moving towards opposite poles. In anaphase II (Fig. 20i), separating chromatids reach at the poles.

Chiasma Frequency

Chiasma frequency in *Acrotylus humbertianus* was found to be 4.4±2.07 SE and terminalization coefficient was found to be 0.63 (Table 3).
Chromosomal anomalies

An anaphase bridge in late anaphase II stage was observed as chromosomal anomaly (Fig. 20j).

*Tristria pulvinata* Uvarov.

The individuals of *Tristria pulvinata* were collected from rice fields and were available from August to November (Table 1). These were brownish green in colour, having cylindrical, elongated smooth body with forwardly directed antennae. These individuals were found in groups of 6 to 10.

2n number in the males of *Tristria pulvinata* is 23 (Fig. 21a) and in females it is 24 (Fig. 21b). All the chromosomes of the complement are acrocentric (Fig. 21a, b). Male karyotype consists of eleven pairs of autosomes and a single X chromosome (Fig. 21c). Out of these, three pairs are long (L1-L3), six pairs are of medium size (M4-M9) and two pairs are of short chromosomes (S10-S11). X chromosome is the largest member (Fig. 30j) of the complement having relative length of 14.012±0.275 SE. In autosomes, the relative lengths range from 3.762±0.07 SE to 11.932±0.07 SE (Table 2).

In females, 2n=24 and all the chromosomes are acrocentric. Among autosomes, there are three pairs of long chromosomes, six pairs of medium size chromosomes and two pairs of short chromosomes (Fig. 21b). XX chromosome pair is the longest pair in the complement.

Meiotic Stages

In zygotene (Fig. 22a), the chromosomes are highly condensed and coiled around each other forming an indistinct structure. During pachytene stage (Fig. 22b), the condensation of the homologous chromosomes is more and the bivalents appear thicker. The condensed bivalents start moving apart from each other and
get separated except at chiasmata during diplotene (Fig. 22c). During diakinesis, the bivalents and autosomes are distinctly visible. The autosomes exhibit various shapes such as rods, crosses, stars and rings (Fig. 22d). During metaphase II (Fig. 22e), the highly condensed chromosomes are arranged in bivalents and get oriented on equatorial plates.

**Chiasma Frequency**

Chiasma frequency calculated from metaphase I and diakinesis stages was found to be 9.6±1.67 SE and terminalization coefficient was found to be 0.66 (Table 3) in this species.

**Chromosomal anomalies**

Chromosomal anomalies such as stickiness (Fig. 23a) and stretching (Fig. 23b) of chromosomes were observed. In the former, the chromosomes are clumped and in the latter, they get stretched.

**Family Pyrgomorphidae**

**Subfamily Pyrgomorphidinae**

Two species of grasshoppers belonging to the family Pyrgomorphidae were recorded and studied cytologically. These species belong to the subfamily Pyrgomorphidinae and in both the species 2n=19 in males and 2n=20 in females.

*Atractomorpha burri* Bol.

The individuals of *Atractomorpha burri* were collected from the grass fields in the months of November and December (Table 1). The individuals of this species are green coloured, stout, having conical head, stout antennae, oval light coloured eyes and green slender legs.

Diploid chromosome number (2n) in males is 19 (Fig. 24a) and in females, it is 20. (Fig. 24b). All the chromosomes are acrocentric (Fig. 24a, b). Male
Karyotype prepared from spermatogonial metaphases reveals that it consists of 9 pairs of autosomes and a single X chromosome. Based on the relative length data, the autosomes are divided into three categories. There are four pairs of long (L₁-L₄), three pairs of medium (M₅-M₇) and two pairs of short (S₈-S₉) chromosomes (Fig. 24c). The relative length of the longest chromosome pair is 16.164±0.07 SE and that of the shortest chromosome pair is 4.235±0.13 SE (Table 2). Relative length of X chromosome is 10.029±0.12 SE which is intermediate between L₃ and L₄ autosomeal pair (Fig. 30k).

Female karyotype from somatic metaphases, also shows four pairs of long, three pairs of medium, two pairs of short chromosomes and a pair of X chromosomes (Fig. 24b).

Meiotic stages

In zygote (Fig. 25a), the bivalents are not clearly visible but they are coiled around each other forming a coiled mass of chromosomes. Metaphase I (Fig. 25b), reveals the presence of 9 autosomal bivalents and an univalent X chromosome arranged equatorially. In metaphases II (Fig. 25c), the chromatids are wide apart from each other, and their arrangement on the equatorial line is in circle. Chromatids of each chromosome separate normally and start moving towards opposite poles during anaphase II (Fig. 25d).

Chiasma Frequency

The mean chiasma frequency was found to be 6.00± 0.6 SE and terminalization coefficient was found to be 0.66 (Table 2).

Chromosomal anomalies

Chromosomal anomalies observed in this species are diffused chromosome (Fig. 26a), haploid metaphase (Fig. 26b) and polyploid stage (Fig. 26c).
*Atractomorpha crenulata* Fabr.

The individuals of this species were collected from the grass fields and occur from August to November (Table 1). The individuals of this species are green colored having long and slender compressed body, conical head, short and stout antennae and oval yellow coloured eyes. Legs are slender and green in colour.

Diploid chromosome number (2n) is 19 in males (Fig. 27a) and 20 in females (Fig. 27b). All the chromosomes are acrocentric (Fig. 27a, b). Male karyotype from the gonial metaphases shows that it has 9 pairs of autosomes and a single X chromosome. There are three pairs of long chromosomes (L₁-L₃), five pairs of medium chromosomes (M₄-M₈) and one pair of short autosomes (S₉) (Fig. 27c). X chromosome is the largest member of the karyotype (Fig. 30). The relative length of the longest autosomal pair is 12.366±0.12 SE and that of the shortest pair is 5.004±0.16 SE Relative length of the X chromosome is 13.417±0.27 S.E (Table 2).

Somatic metaphase plates of females show that 2n=20 (Fig. 27b), and all the chromosomes one acrocentric. There are three pairs of long, five pairs of medium, one pair of short autosomes and a pair of X chromosomes.

**Meiotic stages**

The meiosis was studied in male and different meiotic stages observed are as follows:

During zygotene stage (Fig. 28a) the bivalents are not clearly visible, but coiled mass of the chromosomes is seen. Because of the condensation of the bivalents, the chromosomes get shortened during diplotene (Fig. 28b). Synapsed chromosomes are held together at one or more chiasmata. Condensed chromosome appear in various configurations such as rods, stars and rings as observed in diakinesis (Fig. 28c). In metaphase II (Fig. 28d), the chromosomes are arranged on
equatorial line with widely separating chromatids which reach at respective poles in anaphase II (Fig. 28e).

**Chiasma Frequency**

Mean chiasma frequency was found to be $6.2\pm0.80$ SE and the terminalization coefficient was found to be 0.67. (Table 2).

**Chromosomal anomalies**

Chromosomal anomalies observed in this species are uncondensed metaphase I (Fig. 29a), uncondensed metaphase II(Fig. 29b) and metaphase II despiralization. (Fig. 29c).

Thus main findings of the present study are: Cytology of 11 species of grasshoppers from Himachal Pradesh have been reported. Out of these, 9 species belong to Acrididae and 2 species belong to family Pyrgomorphidae. Sex determination mechanism in all these epecies is of XO–XX type. Eight species are new record from the region. The karyotype and male meiosis of these species have been studied and chiasma frequency and terminalization coefficient have been calculated.