Diversity of the living form is so enormous that it shakes the confidence of a worker in his ability, at first sight, to achieve any worthwhile result from his efforts at understanding the many faceted phenomenon of life. It redounds to the credit of the pioneers of the science of biology that a semblance of order and uniformity have been hammered out of myriads of species of animals and plants. Perhaps many more millions of species both of plants and animals remain to be brought under the discipline of systematics in which the old criteria of morphological characters are gradually giving way to physiological, biochemical and immunological characters under the impact of modern work in the above mentioned disciplines of biology.

In fact evidence is fast accumulating to show that many vital processes of a plant or an animal follow more or less similar metabolic pathways. Thus for example protein synthesis or fat metabolism show striking similarity in diverse species of organism. The process of respiration which is essentially concerned with energy conversion in an organism defies the diversity of multitudinous forms and functions by treading almost a
beaten track. The few basic building blocks of DNA and RNA, pervading through the entire biological world in various permutations and combinations point to another classic example of the fundamental uniformity in diversity of the living matter.

These recent advances in biology have engendered a hope in the workers that within a measurable period of time the diversity of form and function will be traced to a few fundamental metabolic patterns; and further that these fundamental metabolic patterns will be resolved in terms of energy incorporation and conversion by the organism.

One must, however, hasten to add that many a billion DNA - helix has to twine and untwine before a glimpse of biological reality can be obtained. This becomes clear when one considers the fact that very little sustained physiological and biochemical data have been obtained from the evolutionary point of view for a group of varieties or related species or genera. Even in the study of growth and development of crop plants in relation to the changing environment the above mentioned aspect of study has been neglected. A study of differential responses of different varieties and species of a crop
plant to different environments will be of immense value in selection of varieties for different localities as well as for undertaking plant breeding work on scientific lines.

The diversity of form and function are manifested in responses of different plant species to environment, especially to temperature and light-period which individually as well as collectively leaves a profound impress upon their growth and developmental patterns. If, however, an integrated study of the effect of different levels of photoperiod, temperature and other factors is undertaken on a group of varieties or species of a crop plant the relationship between the patterns of growth, flowering, metabolism, regulatory mechanism and energy requirement will become clear. Such studies are likely to prove fruitful in integrating the numerous tits and bits of physiological, biochemical, genetical and other informations into an integrated picture of the living entity.

Such correlative studies of growth, yield, flowering and environmental responses of a large number of varieties and species of different crop plants have been undertaken by Chinoy and his coworkers. This work has necessarily involved the giving of photoperiodic and
vernalization treatments to different varieties and species of crop plants and analysing growth, development, metabolic drifts of regulatory and nutritional substances - both organic and mineral and lastly the yield, as well as factors determining the yield in relation to the environment.

Work on a large number of varieties of wheat, oat, barley, gram, rye, wheat-rye hybrid and other crop plants grown at different places has revealed that all the major growth and yield characters of plants, such as rates of photosynthesis and respiration, height, tiller production, number of leaves, fresh and dry weight of stem, leaf, ear and root, number of spike, spikelet and grain, length of spike, weight of grain, 1000 kernel weight and other growth characters are correlated with the length of the vegetative period (for references see the historical part of the thesis).

The relationship between developmental process, growth, yield and environmental factors was confirmed by growing varieties of crop plants belonging to different classes of flowering under varying combinations of vernalization and photoperiodic treatments. Metabolic drifts of nutritional and regulatory substances such as carbohydrates, minerals, vitamins and auxins were also found to be correlated with the developmental process of a plant.
Photoperiodic responses of different varieties of these crop plants were found to be correlated with its time of flowering thus suggesting a quantitative relationship between the amount of energy utilized by the plant and some of its major physiological processes.

On the basis of these correlations in plants the inheritance of growth yield and developmental characters was studied by making crosses between different varieties of crop plants belonging to different classes of flowering and growing the parents as well as F1 and F2 hybrids under different photoperiods with and without vernalization. Hybrid plants showed the same correlations between growth and development as shown by homozygous genotypes flowering at different times; and their response to change in the environment was also similar.

Keeping in mind this integrated picture of growth, development, yield and other characters the present writer was encouraged to undertake similar studies in Linseed. The object of these investigations was to determine whether there are correlations between different components of growth and the developmental process of linseed. Further whether the mineral metabolism was in any way related to flowering of linseed. Yield characters
have also been studied in the same way. The energy requirements of the two varieties under study have also been determined. On the basis of these detailed studies the behaviour of the hybrid population of a cross between the two varieties and its reciprocal has been studied under two photoperiods long day and normal day. It appears as if the same correlative law is obeyed by linseed hybrids and their homozygous parents.

**REVIEW OF LITERATURE:**

It may be stated at the outset that in absence of facilities for growing plants under controlled conditions photoperiodic and vernalization treatments have proved handy in accelerating or retarding the developmental process. It was found necessary to change the time of flowering of a variety for studying its effect upon growth, grain yield and uptake of nitrogen, phosphorus and potassium. Further by changing the time of flowering of a variety its ripening period was brought within different ranges of temperature, thus enabling one to study the effect of temperature upon grain yield and 1000 kernel weight. Lastly by providing the hybrid population with different photoperiodic regimes one could study the changes brought about in segregation pattern.
Keeping the above mentioned objectives in view the present review will deal with the various aspects of researches in developmental physiology and physiogenetics in their correct historical perspective.

Development: Klebs (1918) carried out his pioneering work on the developmental physiology of plants. Based upon his studies on the influence of daily duration and composition of light and temperature on growth and development, he postulated three phases of development: (i) ripe-to-flower condition; (ii) initiation of flower primordia; and (iii) actual formation of flower and inflorescence. The first phase postulated by Klebs is purely qualitative in nature and is not recognisable morphologically. The second and the third phases are quantitative and can be morphologically recognised.

The work of Garner and Allard on the photoperiodic responses of plants was another important landmark in our understanding of developmental physiology. Garner and Allard (1920, 1923) classified plants as short day, long day and indeterminate or day neutral on the basis of their response towards the daily duration of light and dark periods. Since then a considerable amount of work has been done on photoperiodic induction, short-day plants, photoperiodic classification, endogenous rhythms, phytochrome red-far-red

Interaction of light and temperature: Increasing evidence has accumulated to show that the photoperiodic response of a plant is greatly dependent upon the prevailing temperature. Gassner (1918) found that winter rye plants when germinated at low temperature reached the shooting stage much earlier than those germinated at a higher temperature. Gilbert (1926, 1926a) found that response to relative daylength is materially influenced by the particular temperature and humidity conditions
prevailing during the growth period. He found a considerable hastening of flowering by low temperature in long day plants and by high temperatures in short day plants. Dolgusin and Lysenko (1939) reported that pretreatment of germinating seeds of winter cereals with low temperature (vernalization) could make them behave like spring varieties. According to the theory of phasic development (Lysenko, 1935), the thermophase must precede the photophase before winter wheat could come to flowering. Purvis (1935), and Purvis and Gregory (1937) have shown that the thermostage is not obligatory. They have also questioned the concept of a strict sequence of phases and postulated two reactions, one controlled by temperature and the other dependent upon a photocatalytic process for development. The importance of temperature in photoperiodic responses has been stressed also by Berkley, (1931); Plitt (1932); McKinney and Sando (1935); Thompson (1939); and Bonner Bakhteyev (1935); Hamner (1938); Von Denffer, (1939); Naylor (1941); Rudorf and Schroek (1941); Borthwick et al. (1941, 1942, 1943); Lang and Melchers (1943); Sirzar (1948); and Went (1944, 1945, 1948). It has been reported by Nanda and Hamner (1958, 1959a, 1959b) that temperature has a profound influence on the photoperiodic responses of Biloxi Soybean. They observed that low temperature during the 8-hour
showed that there occurred a slight shift in the flowering rhythm related to cycle length. They further reported that flower initiation occurred even in plants exposed to 32 hour photoperiod when the temperature was low 12°C. The same workers in another communication (1959b) reported that the flower bud initiation showed a rhythmical pattern in the photoperiodic reaction of Biloxi soybean with maxima and minima occurring at 24 hour interval in plants exposed to dark period at 23°C. The duration of the rhythm is increased to 30 hours when plants are exposed to 17°C during the dark period and to 36 hours when the temperature during the dark period is still further lowered to 10°C.

A close relationship exists between the developmental process in wheat and the total amount of energy supplied. The energy can be supplied to the plant in the photo or thermic form within certain limits. The amount of photo or thermic energy received by different varieties of wheat during their vegetative periods was calculated for plants subjected to different vernalization and photoperiodic treatments and it was found that the products of photo and thermic quanta of all varieties agreed closely under different treatments (Chinoy, 1956). In other words every variety requires a certain quota of photothermic energy.
that should be provided to it before it can flower. The length of the vegetative period was, thus, dependent upon the rate at which the requisite photothermic energy is supplied to the plant. Chinoy, Nanda, Sirohi and Sawhney (1959) reported that in the case of wheat, with an increase in the photoquantum of a variety, there was a corresponding decrease in the thermic quantum. While the photoquantum increased, the thermic quantum decreased from SD to LD treatments in all the varieties. Products of photo-and thermic quanta (photothermic quantum) of all varieties under different photoperiodic and vernalization treatments agreed closely for a variety under different treatments. These workers also reported that the photothermic quanta of late varieties were greater than those of early varieties and as such late varieties required greater amount of photothermic energy to complete their developmental process as compared to early ones. They concluded that photothermic and vernalization quanta could be considered as indices of energy requirement of long day plants. Nanda and Chinoy (1960, 1960a) reported in the case of Cicer arietinum Var. N.P. 9 that there existed an inverse correlation between the photoquantum and the thermic quantum up to the stage of bud initiation. Earlier Berkley (1931) had observed that temperature differences could be substituted for day length
in certain combinations. The term photothermal induction was suggested by Owen et al. (1940) to signify induction in flowering by both light and temperature.

**Influence of development on growth and morphogenesis:**
Considerable experimental evidence is available regarding the effect of developmental process on growth. Murneek (1926) demonstrated the inhibitory effect of developing flowers and fruit on vegetative growth. More or less specific stimulations of vegetative growth coincident with flowering and fruit setting have also been reported by Murneek (1937, 1939). Wittwer (1943) showed that a period of renewed growth follows the phases of synapsis and syngamy as a result of disbudding, deflowering and defruiting.

Tincker (1925) working with different crop plants reported that many varieties of *Dactylis glomerata* attained the greatest height in full summer day. Lubimenko and Szeglova (1928) found that production of dry matter per light hour was greatest with 8-10 hours of illumination in *B. tuberosa* and *Phaseolus*, while in all other species maximum dry weight was obtained with full day length. Length of the day was also reported to affect the length and number of internodes and the number and area of leaves. Barkley (1931) found an increasing vegetative growth with an increase in
either temperature or day length from the minimum. Francis (1931) reported in some caryophyllaceous annuals that the plants under continuous light were taller and more slender than the controls and they produced fruit and seeds when controls were still in the rosette stage. Darrow et al. (1934) observed vigorous growth of tomato plants under continuous illumination. Smith (1933) noted that the effect of different photoperiods on the rate and amount of growth varied according to the particular stage of development. On the basis of his studies on a world collection of 8000 varieties of maize Kuleshov (1933) concluded that vegetative characters such as height, leaf of number etc. are related to the vegetative period of the plant. Purvis (1934); Gregory (1935); and Purvis and Gregory (1937) showed that flowering in winter rye could take place only after a minimum number of leaves were produced. These results were confirmed by Von Denffer (1939). Evans and Allard (1934) found that earliness in different strains of Timothy is a matter of adjustment of the plant to the length of the day. The leaf area of Impatiens balsamina was reported to be the same in normal, sixteen-and twenty hour day by Austin (1935) but less in 8 hours. Singh et al. (1938) found that leaf area, number of leaves, root length, tiller production and nodulation in Crotalaria juncea increased
with increasing photoperiods. Singh and Chaudhari (1933) observed that stem elongation and branching were retarded in photoperiods of less than 12 hours. McKinney and Sando (1935) showed that the number of leaves formed before spike differentiation in wheat was influenced by temperature during germination and the photoperiod immediately following. Kopetz (1936, 1937a, 1937b, 1943) held that a plant requires a certain minimal period of development up to the time of flowering which remains constant for the species. Konovalov and Frolova (1939) found the number of tillers in wheat inversely related to the rate at which plants reached sexual maturity. Sircar and his coworkers (Sircar, 1942, 1944, 1946, 1948; Sircar and Parija, 1945, 1949; Sircar and De, 1948) investigated the growth and development of rice. It was reported that a considerable reduction in the flowering duration of the main shoot of variety Rapsail from 133 to 47 days and of Patnaik from 136 to 79 days was accompanied by a reduction in leaf and spikelet number as well as grain yield. Absorption of nitrogen and synthesis of proteins were found to increase markedly under short day treatment.

Work on a large number of varieties of wheat, oat, barley, linseed, gram, rye, wheat-rye hybrid (Triticale of Arne Muntzing) and other crop plants grown at different
places has revealed that all the major growth and yield characters of plants, such as rates of photosynthesis and respiration, height, tiller production, number of leaves, fresh and dry weights of stem, leaf, ear and root, number of ears, spikelets and grain, length of ear, weight of grain, 1000 kernel weight and others are correlated with the length of the growth period (Chinoy, 1947, 1949, 1955, 1957a, 1960, 1960a, 1961b, Garg, 1960; Nanda, Grover and Chinoy, 1957, 1957a; Nanda and Chinoy, 1957, 1957a, 1958; Sawhney et al., 1959; Sirohi, 1956; Sirohi et al., 1959; Nanda, Chinoy and Sawhney, 1958, 1958a; Chinoy and Sharma, 1957, 1958).

The relationship between developmental process, growth, yield and environmental factors was further studied by growing varieties of crop plants belonging to different classes of flowering under varying combinations of vernalization and photoperiodic treatments. In spite of the widely varying environmental conditions the above mentioned correlations were confirmed (Chinoy, 1949a, 1950; Chinoy and Nanda, 1946, 1950, 1951, 1951a, 1951b; Chinoy, Sawhney and Nanda, 1958; Nanda and Chinoy, 1945, 1957, 1957a, 1960, 1960a; Nanda, Chinoy and Sirohi, 1958, 1958a, 1958b; Nanda et al. 1959).
Physiochemical changes in the growing points as well as in developing kernels and germinating seeds have also been studied. Varieties of crop plants varying widely in their phasic development were grown under varying photoperiodic and vernalization treatments and metabolic drifts of regulatory substances such as enzymes, vitamins, and auxins, as well as of nutritional substances both organic and mineral, were studied (Chinoy, Grover and Nanda, 1957, 1961; Chinoy, Nanda and Garg, 1957, 1957a; Chinoy, Singh and Sirohi, 1957; Chinoy, Grover and Sirohi, 1957; Chinoy and Sharma, 1958; Chinoy and Nanda, 1959; Garg et al. 1957, 1958; Garg, 1960; Grover et al. 1958; Gupta, 1956).

It was found that most of the internal characteristics of different varieties were correlated with their developmental process. None of the major physiological processes of a plant was disjoined and independent of others. They were interrelated to form a fully integrated system to carry on two composite and correlated processes of growth and development of the plant. Another interesting conclusion that emerged from these studies was that the rates of production and utilization of regulatory substances were different in different varieties. These differences were, however, linked with the development of the plant, and were either accelerated or retarded by changes in the environmental conditions in the same manner as development.
The most important of these regulatory substances was found to be ascorbic acid, which not only reached a high level of concentration earlier in an early flowering variety, synchronizing with the change in the growing point from the vegetative to the reproductive state, but also attained a similar high level earlier when a late flowering variety was made to flower earlier by growing its plants after vernalization in the long photoperiod (Chinoy, Singh and Sirohi, 1957; Chinoy, 1962).

Khalil (1956) has also demonstrated a linear relationships between the number of leaves formed on the wheat plant and the length of vegetative period. In millet *Panicum miliaceum* var. p.v. 36 stem elongation is very much accelerated in SD and ND plants, while the increase in height is very slow and gradual in LD plants (Nanda, 1958). This investigator has conclusively shown that the pattern of branching and stem elongation of this millet under different photoperiodic treatments closely corresponds to its flowering behaviour thus confirming the correlation between growth and development that has been found to exist in wheat and other plants. Garg and Chinoy (1964) have shown that the rate of stem elongation is correlated with the pace of development and the vegetative and reproductive differentiation as well as growth and development are governed by a common regulatory mechanism.
Gene action: A number of comprehensive publications on inheritance of qualitative characters and gene action are available in literature. (Anfinsen, 1961; Brink, 1960, 1962; Burnham, 1962; Caspari and Thoday, 1964; Demerec, 1941, 1951, 1956; Goldschmidt, 1955; Haldane, 1954; Freese, 1963; Hudon and Richens, 1946; Levinthal et al., 1963; Marmur and Schildkraut, 1963; McElroy and Glass, 1957; Morell, 1962; Meselson and Weigle, 1963; Muntzing, 1961; Pontecorvo, 1958; Rhoades, 1955; Ruhland, 1955; Sager and Ryan, 1961; Smith, 1944; Timofeeff-Ressovsky, 1940; Waddington, 1957; Wagner and Mitchell, 1955; Wittmann, 1963; Wright, 1953; Zamenhof, 1956). However, it would be well to summarize a few salient features of the work here.

Beadle (1945, 1957) put forward the concept of one gene - one enzyme and subsequently modified it to that of one gene - one primary function. Benzer (1957) elaborated the action of the gene into three entities, viz., recon, muton and cistron, in which the last one is considered as the functional unit. Schmitt (1956) has visualized gene action as a resultant of specific juxtaposition of two or more macromolecules and not as an individual macromolecule or a part thereof. Pontecorvo (1958) has demonstrated parasexual processes in genetic recombination, which is similar to the phenomenon of transduction.
Further, various other advances in genetic studies, such as, formation of merozygotes (Wollman, Jacob and Hayes, 1956), studies of episomic changes which are recognized as nucleo-cytoplasmic interactions (Jacob, Schaeffer and Wollman, 1960), studies on the co-ordinated unit of action within the chromosome - the Operon (Jacob, Perrin, Sanchez and Monod, 1960; Pardee, Jacob and Monod, 1959), and the role of cytoplasm in determining gene action (Rhoades, 1955; Nanney, 1957 and others) have also helped in advancing our knowledge of heredity and variability. The active mass and rate concepts of the gene suggested by Goldschmidt (1938) as well as attempts to work out the dynamics of gene action in terms of the rate of metabolic and biochemical processes have also advanced our understanding of the complex mechanism involved in the heredity and the variability of form and function.

A review of the voluminous literature on gene action leaves one with the impression that two main views hold the field: (i) the concept of the "Master Molecule"; and (ii) the "Steady State" concept. It would be well to analyze the situation in the light of recent advances in our knowledge of gene action.
Chinoy (1957, 1964) has suggested that the production of a primary gene product like a vitamin will depend ultimately upon the energy incorporating and energy utilizing mechanism of a plant and therefore the ultimate resolution of the genetic complexity will depend upon our knowledge of energy relations of a plant.

**EXPERIMENTAL PROCEDURE**

The work presented in the thesis has been carried out on two varieties of linseed. The experiments were repeated during three successive growing seasons. As the results obtained were basically similar, the data of one season only are presented here. The varieties selected were as follows:

**Linseed (Linum usitatissimum):** Var. Bengal 514 (P₁) and Var. N.P. 121 (P₂). These varieties were selected for their economic value and fairly wide differences in their growth period and performance.

**Vernalization treatment:** Graded seeds were germinated in silica sand at 25 - 30°C in enamelled dishes. Both the seeds as well as the dishes were sterilized before use. Each dish contained 360 seeds and was provided with 70 ml.
of water. Germination started after twenty four hours and was allowed to continue for three days during which time the two cotyledons had emerged from the seed coat and the seedling had attained a length of 1 - 2 cm. At this stage some more sterilized sand was sprinkled so as to cover the seeds completely and after moistening the sand the dishes were transferred to a refrigerator maintained at 3 - 5°C. As moisture in the dish was replenished whenever necessary the growth was restricted only by the low temperature during the process of vernalization. It has already been shown that more uniform vernalization effect is achieved when water supply is not restricted and the seedling is allowed to grow freely (Chinoy, 1956). The vernalization treatment was given for 32 days.

Unvernalized sets of seeds were kept for germination at room temperature seven days before the termination of the vernalization treatment so as to bring them to the same stage of growth as the vernalized set at the time of transplantation. Both these sets were transplanted in the field on the last day of the vernalization treatment in well manured plots (6.0 x 4.5 meters) each of which was divided into three equal plats. The seedlings were 5 cm. transplanted in holes/deep and 4 cm. apart from one another. Vernalized and unvernalized seedlings were transplanted in alternate rows.
Manuring, watering and thinning: In order that nutrition may not become a limiting factor, 50 g. of ammonium sulphate dissolved in water, was given to each plot at weekly intervals. The first dose of this fertilizer was given soon after transplantation followed immediately by an irrigation. After this the plots were watered twice a week regularly. When seedlings had established themselves, thinning was done to leave a distance of 3 cm. between plants.

Photoperiodic treatment: After the seedlings had established themselves (30 days after transplantation), they were exposed to the following photoperiodic schedule:

1. Short day (SD) . . . 8 hours of day light alternating with 16 hours of darkness.

2. Normal day (ND). . . . Natural daily illumination during the months of October to April with a mean photoperiod of about 11 hours alternating with 13 hours of darkness.

3. Long day (LD) . . . 19 hours of light alternating with 5 hours of darkness. The daylight was supplemented by four incandescent lamps of 200 watt each. The intensity of natural as well as
artificial light was measured with the help of West on light meter. The range of variation for natural light was between 1500 and 7500 foot candles and that for artificial light was between 40 to 70 foot candles.

These light treatments have been referred to by their abbreviations in the text. The arrangements for giving long day and short day treatments have already been detailed elsewhere (Chinoy and Nanda, 1951).

**Growth data:** The methods of growth analysis developed by Gregory and his collaborators (1921; 1926) and extensively used by Chinoy and his co-workers (1959) were used for these experiments. Following observations were recorded during the course of these experiments.

**Height, branch and leaf number:** Weekly records were maintained of height and branch production in plants selected by the method of random numbers from various treatments. Six plants from each treatment, were used for these growth measurements. Height was measured from the surface of the soil to the tip of the shoot apex. Total number of branches and leaves of the same plants were also recorded weekly.
Fresh and dry weights: Plants were selected according to the method of random numbers from each replicate for sampling at fortnightly intervals. Care was taken to uproot the plants without damaging their roots. The plants were thoroughly washed and brought to the laboratory in wet cloth bags. They were then separated into green leaves to represent the assimilating material, stem to represent the conducting and mechanical tissue, roots to represent the absorbing tissue and fruits to have an idea about potential crop. These plant parts were weighed separately.

For the first two samplings 15 plants from each treatment (5 from each replicate) were taken. For the third sampling 9 plants from each treatment and later on 6 plants from each treatment were taken for fresh weights. After recording fresh weights these samples were placed in an oven at 80°C. for three days and dry weights of these separate plant parts were then determined.

Chemical analysis: The periodic samples of dried plant parts were then powdered and passed through a fine sieve of 100-mash and then analysed for nitrogen, phosphorus, and potassium by methods outlined below:

Estimation of nitrogen: A micro-kjeldahl method modified to suit the requirements was used for N estimations. A modified micro-kjeldahl distillation apparatus was devised
wherein the solutions were transferred by automatic suction arrangement, thereby eliminating the necessity of disconnecting the apparatus and avoiding all possibilities of the leakage of ammonia. The method was as follows:

About 0.1 g. of the dried and powdered material was weighed and placed in the micro-kjeldahl flask, 5 ml. of 3% salicylic acid in concentrated H$_2$SO$_4$ were added and the flask was shaken at intervals for about 10 minutes to ensure thorough mixing. 0.5 g. of sodium thiosulphate was then added to it and when initial frothing subsided, the flask was heated on a low flame, till frothing ceased. This took about 20 - 30 minutes. After cooling for a few minutes 1 g. of sodium sulphate and a pinch of anhydrous CuSO$_4$ were added and the flask was heated on a medium flame. It was carefully rotated from time to time to bring down organic matter sticking to its sides, so that thorough digestion may take place. The whole mass turned black and then dark brown. The heating was continued till the digestion was completed and a clear blue liquid was obtained. The flask was then removed from the flame and allowed to cool down to room temperature.
The digested material was diluted with little water (20 - 25 ml.) and sucked into the micro-distillation apparatus with the help of a filter pump. The flask was washed two or three times with 2 - 3 ml. of water and these washings were also sucked into the distillation apparatus with one or two drops of phenolphathleim having been added to the last wash. Finally sufficient saturated solution of NaOH (Ca. 25 ml.) was sucked in, till the solution turned pink. 5 ml. of standard H₂SO₄ were placed in the receiver (50 ml. flask) with a drop of phenolphathleim in it, taking care that the receiver tube of distillation apparatus dipped in the acid. The entire condenser was thoroughly rinsed and washed before use. The fixing of the receiver containing 5 ml. of standard H₂SO₄ and rinsing of the condenser were done before the saturated NaOH was sucked into the distillation apparatus because the action started immediately. Distillation of ammonia was carried out by heating the distillation flask slowly at first and vigorously later. Finally steam was passed into the apparatus to complete the process. During the whole process of distillation an adequate suction was maintained with the help of a filter pump in order to facilitate rapid absorption of ammonia into H₂SO₄ in the the receiver. The distillation was continued till at least
one third of the liquid was distilled over and collected in the receiver. After distillation the condenser was rinsed and the nozzle of the condenser was also washed with water and this liquid was collected in the receiver.

The excess of H$_2$SO$_4$ in the receiver was titrated against N/100 NaOH solution. This determined the volume of acid actually used by ammonia vapours. This was multiplied by the N-factor (0.0014) and N content of the given sample was determined.

**Estimation of potassium and phosphorus:** The sieved sample (0.05 - 0.1 g.) was transferred to a 30 ml. Kjeldahl flask and to this 5 - 6 ml. of concentrated HNO$_3$ were added and warmed gently till completely dissolved. 5 ml. of oxidising agent (50 g. of NH$_4$NO$_3$ in 25% HNO$_3$, made up to 100 ml.) were added and the solution was heated gently to expel water, so that the oxidation proceeded in a melt of NH$_4$NO$_3$. If necessary, more of oxidising reagent could be added from time to time and heating continued vigorously till brown colour of the solution disappeared and a clear melt was obtained. When oxidation was complete, the flask was heated more vigorously to volatilise off the excess of NH$_4$NO$_3$ subliming on the sides of the flask by holding the flask over a free flame and turning its sides carefully.
The residue was dissolved in 2 ml. of concentrated HCl and then evaporated to dryness. It was ultimately used to remove all HNO₃. The left over residue was dissolved in about 10 ml. N HCl and then the solution was evaporated to a very small bulk to ensure complete conversion of metaphosphate into the ortho form. It was then evaporated to dryness on water bath. The residue was finally dissolved in a few ml. of warm water and then a few drops of N HCl were added and the solution was made upto 10 ml. including washings.

1 ml. of oxidised solution diluted with a little quantity of water was taken in a 20 ml. test tube and a drop of methyl orange was added to it. This solution was made just alkaline by adding to it dilute NH₄OH drop by drop; and was made acidic again with a drop of concentrated HNO₃. It was boiled for five minutes on sand bath and then allowed to cool. 1 ml. of 60% NH₄NO₃ was added and then diluted with a little water. The test tube was placed on the bath and after a little warming, 4 ml. of warm ammonium molybdate solution was added drop by drop. The solution was well stirred and placed in an oven at a temperature of 60 - 65°C. for 15 minutes for complete precipitation of the phosphorus as ammonium phospho-molybdate. It was then filtered through a micro-filter tube and washed three
times with 3 ml. of ice cold KNO₃ solution each time. The filtrate was removed and the precipitate was completely dissolved by passing 5 ml. of N/10 NaOH through the micro-filter tube. NaOH was passed at a slow pace to enable the precipitate to be completely dissolved and if need be, a little more of it was passed through. The resulting solution was collected in a 50 ml. test tube. Three washings, each with 3 ml. of water, were given and then the solution in the test tube was boiled to remove ammonia completely. It was immediately corked to avoid contact with air and was allowed to cool. A known quantity of the solution to which a drop of phenolphthalein had been added, was quickly titrated against N/100 H₂SO₄. The volume of N/10 NaOH needed to react with phosphomolybdate precipitate was multiplied with 0.1352 to get the amount of phosphorus in the aliquot.

1-5 ml. aliquot of the oxidised solution (depending on the estimated concentration of the K present in the sample to give sufficient quantity of precipitate for estimations) was taken in a 50 ml. test tube and 0.5 ml. of NaNO₂ and two drops of acetic acid were added. It was warmed for about 10 minutes in the water bath in order to remove any ammonia salts as gaseous nitrogen. Care was taken to avoid too much concentration of the solution.
It was cooled in ice cold water and three drops of acetic acid were added. After stirring 3–4 ml. of freshly prepared solution of sodium cobaltinitrite were added drop by drop. The test tube was well stirred and its sides well scraped for the precipitate sticking to it by means of a glass rod. The test tube was then placed in the refrigerator and stirred two or three times before leaving it overnight. The precipitate was filtered through a micro-filter tube by suction and was washed three times with 3 ml. of ice cold water each time. 3 ml. of N/100 KMnO₄ were added to the precipitate (in excess of what was necessary for dissolving the K ppt.), followed by 3 ml. of 2 N H₂SO₄. The solution was then heated to boiling and filtered through the filter tube. The filtration was so regulated that all the K ppt. got dissolved by adding more of KMnO₄ and H₂SO₄ if necessary. Two washings were given each with 2 ml. of warm water. Sufficient quantity of N/100 oxalic acid was added to the resulting solution till the pink colour disappeared. Oxalic acid was back titrated with standard KMnO₄. The volume of oxalic acid was subtracted from the total KMnO₄ consumed. The amount of potassium in miligrams was calculated by multiplying the remainder of the volume with the K factor which worked out to be 0.3161 under the laboratory conditions.
The results of the estimation of nitrogen, phosphorus and potassium are expressed as percent N, P and K. The total N, P and K contents of individual plant parts and the whole plant were obtained by multiplying the percentage content with the corresponding dry weight of the given part of the plant. The total N, P and K contents of the whole plant were determined by adding up the total N, P and K contents of different plant parts for a particular sample. The absolute rate of uptake of N, P and K was determined by multiplying the mean N, P and K content of a plant during a sampling period by the corresponding relative rate of uptake of N, P or K. Further C/N, C/P and C/K ratios were calculated out and ratios of stem/leaf N, P and K contents were also determined.

Relative growth rate: Relative growth rates of height and of dry matter production of the whole plant, root, stem, leaf, and fruit, in all the varieties of linseed were determined. The rate was determined by taking differences in the Naperian logarithms of successive weekly height determinations in accordance with Blackman's compound interest law of growth in plants (1919). Similarly the relative growth rates of dry matter production in different plant parts as well as in the whole plant were calculated by taking the differences in
the Naperian logarithms of dry weights of successive fortnightly samples.

For convenience of calculations and graphical presentation of the data the values of dry weights were taken for 100 plants.

Net assimilation rate: The net assimilation rates were calculated as shown by Gregory (1926), using the following formula:

\[
\frac{W_1 - W_0}{L_1 - L_0} = \log_e L_1 - \log_e L_0
\]

Where \( W_0 \) and \( W_1 \) represent the successive dry weights of the whole plant; \( L_0 \) and \( L_1 \) represent the successive dry weights of leaves of the corresponding samples. In this manner net assimilation rate per unit dry weight of the leaf for a fortnightly period was calculated. The net assimilation rate per hour of illumination was also calculated by dividing the value by the number of light hours during the period.
Photo thermic quantum: With a view to further elucidating the inter-relationship of light and temperature in growth and development of linseed, photothermic quanta for the two varieties of linseed were calculated as shown by Chinoy (1956). The total number of light hours received by the plants during the vegetative period under different photoperiodic and vernalization treatments were calculated separately for all the observations by multiplying the daily photoperiod by the number of days in the vegetative period. Thus for instance for plants under SD treatment, the daily photoperiod of 8 hours was multiplied by the number of days in the growth period of plants under that treatment. Similarly it was done in the case of ND and LD treatments.

Although records of intensities of illumination were kept, they have not been taken into consideration in the calculation of the total photoperiod during the growth period of a plant. From the records of maximum and minimum temperatures, mean daily temperatures were worked out. The mean daily temperatures during the growth period of a plant under any given treatment were added up and these were used for the calculations of photothermic quantum.
Vernalization quantum was also calculated out by taking the difference between the photothermic quantum of unvernalized and vernalized plants of a given variety. The vernalized plants of the different crop plants were generally found to give lower values of photothermic quanta.

**Developmental data (flowering):** The date of opening of the first flower was taken as the date of flowering. The mean time taken by ten plants per replicate to reach the stage of flowering from the date of transplantation was calculated out and was taken to represent the growth period of different varieties under different treatments.

**Ripening period:** It is the period from the day of flowering to the flint ripe stage of the grain.

**Harvest data:** When the plants under all the treatments were mature harvesting was done and observations for the following characters determining yield were recorded for the two varieties of linseed: Dry weight of the plant, husk and grain yield, seed weight, 1000 kernel weight, number of bolls per plant, number of seed per plant, fertility ratio, boll-branch ratio and seed - dry weight ratio.
Hybridization work: With a view to facilitating the comprehension of the effect of heterozygosity upon the various correlations established between growth and development in linseed, crosses were affected between the two varieties. The main consideration in this work was the selection of parents with an adequate range of variation in their growth periods with a view to noting its effect upon segregation range as seen in the case of the two varieties used for these experiments.

A cross between two varieties of *Linum usitatissimum* Bengal 514 (P₁) x N.P. 121 (P₂) was made; similarly the reciprocal cross was also made.

Seeds of parents and F₁ hybrids were divided into two groups. Seeds of each group were sown in wooden boxes 18" x 12" x 8" filled with loamy soil and farm-yard manure in proportion of 3 : 1. As soon as the seedlings emerged from the soil the boxes of the two groups containing parents, F₁ of the cross and the F₁ of the reciprocal were placed under two photoperiods, viz., (i) Normal day (ND) of 11 hours of illumination; (ii) Long day (LD) of nineteen hours of illumination. Weekly manuring of boxes with 5 and 2 g. respectively of nicifos and potassium sulphate was carried out for 6 weeks. Moisture level in the boxes was maintained at near field capacity (15 - 17%).
The following characters were studied both under ND and LD conditions for parents, as well as F₁ hybrids of the cross and its reciprocal:

(i) Height measurement at weekly interval
(ii) Branch number at weekly interval
(iii) Leaf number at weekly interval
(iv) Growth period in days
(v) Dry weight
(vi) Number of fruits
(vii) Dry weight of fruits
(viii) Number of seed
(ix) Dry weight of seed
(x) Photothermic quantum.

In the second year selfed seeds of all the F₁ plants of the cross as well as its reciprocal were divided into 20 small units of 0.5 g each. These were then randomized into two groups and sown in boxes as described previously for the two photoperiodic treatments. There were approximately 1200 to 1500 seeds in each group of the F₂ generation. A study of the above mentioned characters was carried out for the F₂ generation also.