Vernalisation is defined as the method of inducing early flowering in plants by pretreatment of their seeds at very low temperatures. Chourad (1960) has defined it as the acquisition or acceleration of the ability to flower by chilling treatment.

Some plants flower only when they are subjected to a correct photoperiod. In many plants apart from correct photoperiod, temperature is also an important factor which affects the initiation and development of reproductive organs. In case of annuals the influence of temperature on flowering is secondary to light whereas, biennials show only vegetative growth during the first year and only after prolonged exposure to cold temperatures of winter do they flower in the next season. Majority of plants will not flower if they are not subjected to exposure and will grow vegetatively for an indefinite period. However, if they are subjected to cold treatment followed by correct photoperiod they will flower. *Hyoscyamus niger* has two types of plants— one is annual and the other is biennial. Both of them are long-day plants and when exposed to short day will grow vegetatively. Even the biennial type can be made to flower if its ten days' old seedlings are subjected to cold treatment (vernalised).

The practical utility of vernalisation was mainly exploited by Russian scientists, that by vernalisation

(i) Crops can be produced earlier *i.e.* a crop can be harvested much earlier than the control crop;

(ii) Crops can be grown in the regions where they do not naturally reproduce; and

(iii) Plant breeding work can be accelerated.

Theory of Vernalisation

The development of a plant comprises certain stages which must necessarily be traversed before it can actually start maturing. In the process, the completion of one stage is absolutely necessary for the commencement of the next one. Each of these stages requires—suitable doses of temperature, humidity, light, aeration etc. In lack of any of these conditions further development of plant is checked. They may be as follows:

Thermostage. This being the first stage is quite necessary and is also referred to as vernalisation stage or Lysenko stage. Conditions required for successful passage are

(i) *Temperature*—Low temperature ranging from 0°C to 20°C, according to species and strains in question, is required for this stage.

(ii) *Moisture*—Like temperature, presence of moisture is equally important for neat completion on this stage.

(iii) *Aeration*—Like temperature and moisture, proper aeration is very important and at times in several cases it becomes a critical factor.

(iv) Time required for completion of thermostage varies with environmental conditions and depends on the nature of the plant itself. Response of vernalisation also decreases if the period of vernalisation is interrupted by periods of heat treatments.

Lysenko holds the opinion that flower initials are laid down after this stage has been passed. Thus, this stage is of great consequence. Such seeds are first aroused to activity and then are forced to rest. It is believed that when initial germination begins, it becomes practically a grown up plant in all physiological senses. But due to low temperature further germination is tremendously slowed down. So a plant passes this stage as effectively as a normally growing plant. The embryo remains awakened while it remains still inside the seed.

Photostage. When thermostage is complete, the plant passes through the next stage called photostage. There is a pronounced effect of the relative length of day and night on the production of flowers. This phenomenon is more correctly called photoperiodism. (It has been discussed under a separate heading.)

Third stage. While it is poorly known, it is quite necessary for seed formation and it can be said with certainty that it has some connection with the formation of sexual elements and is associated with gametogenesis. The photoperiod requirement for the commencement of this stage is a little shorter than required for the completion of photostage, in general.

Vernalisation Process

For vernalisation the seeds are allowed to germinate for some time and then are given cold treatments by keeping them at 0-5°C. The period of cold treatment varies from few days to many weeks from species to species. After the cold treatment seedlings are allowed to dry for some time and then sown. They should not be sown immediately after the cold treatment. The drying period also should not be a very long one as with the increase in the drying period the response of vernalisation decreases and it may decrease till the seedlings are completely devernalised. Devernalisation can also be affected if the vernalised seeds are subjected to heat treatment. Response to vernalisation also decreases if the period of vernalisation is interrupted by periods of heat treatment. It is also possible to revernalise the devernalised seedlings.

Though it has been observed that mainly stem apex is the region which perceives the effect of vernalisation but Wellensick (1961-62) has succeeded in vernalising leaves and roots of *Lunaria biennis* also. The response to vernalisation also depends on the duration for which and the temperature at which the seed is subjected to vernalisation. Transmission of vernalisation effects across graft unions occurs. In some plants vernalisation can be affected only after some vegetative growth has taken place.

In contrast to photoperiodic effect which not only prepares the plant to flower but also initiates flowering, vernalisation merely prepares the plants for flowering. During cold periods, winter plants acquire a physiological state of ripeness for flowering.

Not only the seeds but isolated embryos can also be vernalised. It is also possible to revernalise a shoot apex which can be cultured and raised into a whole plant.

Mechanism of Vernalisation

A crowd of scientists attempted to explain the physiological process involved in vernalisation and as a result various theories and hypothesis have been advanced.

Gregory and Purvis performed a series of experiments and concluded that in the process of vernalisation, leaf number is the deciding factor as to when the flowering should take place. Pohl and Cholodny (1935) stated that some substances of hormonal nature may be found in the leaves, and are responsible for vernalisation process. They further observed that the embryo by itself is devoid of hormones for necessary growth and it must receive them from the endosperm. Maxmova performed an experiment in which endosperms of spring and winter varieties of cereals were successfully interchanged. Gregory and Purvis (1936) observed that excised embryos separated completely from the endosperm and grown on agar containing 2 per cent glucose and mineral nutrients alone can be vernalised in the same way as the seeds. By this experiment, it can be visualised that the embryo is able to synthetize hormone from sugar, inorganic nitrogen and salts and in absence of sugar supply the excised embryo fails to show vernalisation response.

To explain the mechanism of vernalisation Lysenko gave a two phasic theory according to which growth and development are two different phases of plant life and an exposure to low temperature treatment is necessary for the change-over from the growth phase to the development phase. The explanations for the mechanism are based on hormones. On the basis of observation of the transmittance of effects of vernalisation from a vernalised plant to a grafted unvernalised plant of henbane, Melcher (1936) said that there exists a hormone which is responsible for flowering. In some plants gibberellin spray on shoots of unvernalised plants can induce flowering. Lang and Melcher (1966) postulated that a hormone called vernalin is produced on the meristematic shoot apex of the embryo due to vernalisation treatment which is responsible for inducing flowering. Lang stated that there is a direct connection between vernalin and florigen. He proposed the following scheme:

Low temperature → Themoinduced conditions → Venralin → Florigen

Chailakhyan (1968) refutes Lang's statement because under long-day conditions vernalins turn into gibberellins. Vernalin hormone is thus the precursor of gibberellin. Vernalin is a doubtful hormone since it seems to move only with dividing cells. On the other hand, uridylic acid and other pyrimidine bases can replace vernalisation (Hirono and Redei, 1966). Direct evidence of a relation to RNA is now available.

Since vernalisation process is dependent on a sequence of biochemical reactions, water and oxygen are indispensable in the vernalisation process. Purvis (1940) stated that seeds must contain at least 90 per cent water of their absolute dry weight for adequate vernalisation. Vernalisation of dry seeds is not possible. It is also not possible to vernalise seeds kept in an atmosphere of nitrogen in spite of the provision of adequate quantities of water. The oxygen requirement is low but absolute. The whole plant also needs oxygen for vernalisation.

The need of oxygen is because for vernalisation respiratory energy is necessary. If respiratory inhibitors are used the response to vernalisation decreases. Devernalisation (removal of vernalisation effects) can be affected by exposure of vernalised plants to high temperatures, an atmosphere of nitrogen or an atmosphere containing high percentage of CO_2 (above 20%).

VERNALISATION IN INDIA

India being a non-industrial country, its wealth lies in agriculture. But to the ill-luck of Indian peasants, uncertainties of weather conditions offer great hindrances in maintaining a good crop. Indian climate does not allow crops to stand for a long period of time in a normal state. During the period of development, crops are usually damaged by frost, high temperature, excessive rainfall and floods. In India, peas *(Pisum sativum)* and arhars *(Cajanus cajan)* crops are damaged every year by frost. Similarly certain strains of wheat at milk stage of maturation are often damaged by high temperature and summer crops like melons and watermelons fall an easy victim to the early setting in of rains.

Under such circumstances utilising vernalisation if the crop could be harvested within a brief span during which no adverse conditions may set in, the conditions of Indian peasantry can be actually bettered. Vernalisation may resolve this problem.

These kinds of temptations and considerations invited Indian scientists. Like other European countries, India, too, became lured by the practical utility of vernalisation. Various attempts were made to vernalise plants. Scientific laboratories were opened and both agriculturists and scientists worked regularly on crop plants like wheat, barley, sugarcane and peas. But that was a hard time to achieve any goal and soon the enthusiasm evaporated because the experiments performed could not yield any positive result.

At the same time, against failure from different places Vivekanand Laboratories, Almora, offered promising results on vernalisation of a number of crop plants like mustard *(Brassica juncea)*, pea, wheat and linseed *(Linum usitatissimum)*. Sen and Chakravarty vernalised *B. juncea* T-27 at two different stages, (*i*) soon after sprouting, (*ii*) seeds with upslit seed coat soaked in water for 24 hours. The result showed definitive earliness of about 23 days in the flowering.

(1) **Rice.** The chief objective of rice vernalisation was to find possibilities of saving the crop from flood and drought. Kar and Adhikary (1945) and Sircar (1948) reported that low temperature vernalisation induced some lateness in flowering of rice crops, whereas, Parija and Pillay (1944) observed that presowing low temperature and anaerobiosis induced flood resistance in certain varieties of rice crops. Hidayatulla and Sen (1941) and Kar and Adhikary (1945) reported that presowing high temperature appeared to induce early flowering in a number of varieties.

(2) **Wheat.** Kar (1940, 1943), Pal and Murty (1941) and Sen and Chakravarty (1945) found that wheat, in general, did not respond to vernalisation. It may be due to their short life cycle. Chinoy (1963) reported that vernalised seeds of NP 165 under long-day, treatment scored increased auxin content.

(3) **Jute.** Kar (1943) studied the effect of vernalisation on jute (*Corchorus capsularis*) and found that presowing cold treatment of seeds led to delayed germination, increased production of green pigments in leaves and more vigorous growth in the early state, but no significant effect could be observed in the date of flowering. Sen Gupta and Sen (1943-44) reported similar results, *i.e.*, no effect of cold treatment on flowering time or on vegetative growth. However, Sen Gupta (1953) observed that cold treatments with longer periods led to some earliness (up to 40 days) of flowering and fruiting. These findings were later confirmed by Kundu, Basak and Sarcar (1959).

(4) **Pulses.** Pal and Murty (1941) and Pillay (1944) found that Gram (*Cicer* sp.) responded to vernalisation which could flower under natural days in summer.