# EFFECT OF VARYING PHOTOPERIODS ON GROWTH AND DEVELOPMENT OF WHEAT

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PHOTOPERIODIC responses of crop plants have been extensively investigated and hypotheses have been put forward by a large number of workers regarding the mechanism by which flowering is induced or inhibited under specific photoperiods. A comprehensive survey of these problems has been recently made by Murneek and Whyte (1948). Work on photoperiodism in the tropics, however, is of a recent date (Sircar, 1948). Singh, Kapoor and Choudhri (1938) showed that wheat did best in 15 hours continuous illumination. Pal and Murty (1941) and Kar (1942–43) found that an exposure of low temperature treated seeds to long days induced earliness in all the wheat varieties. Nanda and Chinoy (1945) noted that long photoperiods as well as short photoperiods, after the completion of photostage, increased pollen sterility, while with natural day length sterility is very much lower. This indicated that beyond a certain extent, long days have only an adverse effect. Pal and Murty (1941) further noted that English Wheat grown under tropical conditions required chilling followed by long days for inducing earliness. In the absence of chilling long days have no effect. In Indian Wheat, on the contrary, chilling is not as important as long days for vernalisation. For yield and normal growth, low temperature was an essential feature; as in summer sowing, the crop yield becomes poor.

The present paper is an attempt to throw further light on the photoperiodic responses of wheat under the soil and climatic conditions of Bikaner (Lat. 28·1° N.; Long. 73·22° E.) and indicates the nature of interaction between variety, age of plant, and photoperiod on the growth characteristics of the wheat plants.

## MATERIAL AND METHOD

Three varieties of wheat, namely NP 165 (early), C 13 (medium) and Kubanka (late ripening), were sown on 1st November 1949 in the plots attached to the Department of Botany. Three plots each 10 ft. × 5 ft. in dimensions were selected for experimentation. Each of these was then divided into three sub-blocks 3 ft. × 5 ft. in size, separated by 6 inches broad ridges in between. These sub-blocks were sown with one of the three varieties arranged at random side by side with other varieties. All the plots were evenly manured with farmyard manure and sulphate of ammonia at 30 lb. N (half and half mixture) per acre. One of the main plots was provided continuous light, the normal sunlight being supplemented by two 100 Watts electric lamps hung at a distance of 2 ft. above the plants. The second main plot was sun illuminated for a period of 6 hours (10 A.M. to 4 P.M.) every day, while for the rest of the day the plot was covered with a black curtain. The third plot was exposed to normal sunshine and acted as control. Care was taken to screen off continuous light so that other plots were not affected.

Short day treatment included 6 hours photoperiod from seedling stage to flowering, while long day (24 hours) treatment consisted of continuous illumination from the seedling to flowering stage. Under Bikaner conditions the average length of day varies as follows:— November 10·45, December 10·25, January 10·35, February 11·10, March 12·0, April 12·50, and May 13·30 hours per day. Additional illumination beyond these intervals was given by electric light.

The experiment thus involved the study of the effects of 3 photoperiods on three varieties of wheat at successive stages of the life-cycle. All observations were recorded at intervals of 30 days on 6 to 10 plants selected at random from each variety under the three photoperiodic treatments. Characters studied included (*a*) external growth attributes, (*b*) fresh and dry weights of plants, (*c*) number and weight of grains per sample, and (*d*) maturation period. All observations on dry weight were subjected to statistical analysis.

## Experimental Findings

A. *External growth characters.*—Plants were taller under normal conditions of illumination when compared with those growing under 6 hours or in continuous light; the poorest stand was recorded in the 24 hours photoperiod. Kubanka showed the maximum height, while NP 165 was poorest under all light treatments. Continuous light had detrimental effect on leaf number, while plants under normal photoperiod showed maximum number of leaves. Kubanka was again the best, while NP 165 was the poorest. Tillering was affected in a similar fashion, with best response in normal illumination. NP 165 showed the largest tillering under all the three light treatments, while Kubanka showed poor tillering under both normal and 6 hours photoperiod. Similarly, the number of ears was least in continuous light, and maximum in normal light. In general, continuous light under the conditions of experiment showed harmful effect on all external growth characters in the three varieties (Table I).

B. *Dry matter accumulation.*—The dry weight of plants was highest under normal light and lowest in continuous illumination. Among the varieties NP 165 appeared better under normal and 6 hours illumination, while Kubanka was better under continuous light. C 13 recorded lowest dry weight under all conditions. So far as the dry matter accumulation in component parts was concerned, the maximum dry weight of roots, stem and leaf was recorded in normal light, and least under continuous illumination. While this was true of all the varieties, some preferential relation between period of illumination and dry weight of different parts was recorded. Thus under 6 hours illumination NP 165 evinced maximum root dry weight; C 13 recorded

TABLE I

*Growth characters of wheat varieties under different photoperiods*

| | 6 hours† | | | Normal light† | | | 24 hours* | | |
|---|---|---|---|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_3$ | $V_1$ | $V_2$ | $V_3$ | $V_1$ | $V_2$ | $V_3$ |
| Height (cm.) .. | 39·8 | 40·2 | 52·0 | 43·7 | 45·5 | 58·5 | 31·2 | 36·4 | 45·2 |
| Leaf number .. | 3·8 | 4·2 | 5·5 | 4·2 | 4·5 | 5·2 | 3·5 | 4·1 | 4·2 |
| Tiller number .. | 13·5 | 11·5 | 9·2 | 18·3 | 13·8 | 12·2 | 8·2 | 6·6 | 8·0 |
| Ear number .. | 12·8 | 7·8 | 5·3 | 17·2 | 9·5 | 6·6 | 6·7 | 5·6 | 6·2 |
| Dry weight per plant (gm.) | | | | | | | | | |
| Dry weight of single plant | 25·6 | 20·3 | 25·1 | 45·6 | 35·3 | 39·6 | 8·8 | 7·3 | 9·7 |
| Leaves .. | 6·0 | 6·0 | 11·3 | 11·3 | 8·4 | 15·0 | 1·6 | 1·5 | 2·3 |
| Stem .. | 8·7 | 9·3 | 8·4 | 13·5 | 11·1 | 12·2 | 2·7 | 2·3 | 3·7 |
| Roots .. | 2·4 | 1·6 | 2·3 | 6·6 | 7·4 | 8·1 | 1·3 | 0·7 | 0·7 |
| Ears .. | 8·5 | 3·4 | 3·1 | 12·4 | 8·4 | 4·4 | 3·2 | 2·9 | 2·8 |
| Yield per plant (gm.) | | | | | | | | | |
| 105 days .. | 0·4 | Nil | Nil | 0·8 | Nil | Nil | 1·8 | 1·6 | 1·4 |
| 135 days .. | 4·3 | 2·0 | 1·6 | 6·3 | 4·4 | 2·1 | Plants harvested | | |
| Number of grains | | | | | | | | | |
| 105 days .. | Shrivelled | No grains | | Shrivelled | No grains | | 60 | 42 | 41 |
| 135 days .. | 144 | 52 | 44 | 215 | 110 | 61 | Plants harvested | | |
| Time taken for flowering and maturation (in days) | | | | | | | | | |
| Flowering .. | 82 | 97 | 130 | 76 | 86 | 124 | 54 | 55 | 60 |
| Maturation .. | 150 | 165 | 180 | 150 | 160 | 175 | 125 | 125 | 130 |

*Observations at 105 days.
†Observations at 135 days.
$V_1$ = NP 165.
$V_2$ = C 13.
$V_3$ = Kubanka.

maximum dry weight of stem under similar conditions; Kubanka showed maximum leaf dry weight under all conditions. Highest ear dry weight was also recorded for normal light and least for continuous illumination. NP 165 appeared the best in so far as this character was concerned, followed by C 13 and Kubanka in decreasing order (Table I).

C. *Flowering, maturity and grain characters.*—In all the three varieties earliness was induced by continuous light as compared to normal illumination. Ear formation was earlier by 22 days in NP 165, 31 days in C 13 and 64 days in Kubanka. Reduced illumination period, on the contrary, increased the period of initiation of flowering by 6–11 days in different varieties. Photoperiods also induced variation in flowering dates by 10–48 days under normal light, 15–48 days under 6 hours and 1–6 days in continuous light. Similarly period of maturity in all the three varieties was reduced from 25–45 days under continuous illumination, while practically no change was noted under 6 hours illumination. Varietal differences in maturity period were more marked under normal and reduced light, but not so marked in 24 hours photoperiods.

At 105 days in the life-cycle no grain formation in C 13 and Kubanka was observed under normal and 6 hours photoperiods. NP 165, however, did show some grain formation under such conditions. Under continuous illumination all varieties showed grain formation, but varietal differences were less marked. At 135 days, however, some grain formation took place even under normal and 6 hours duration in all varieties. Normal light plants showed higher yield.

## Discussion

A critical examination of the growth characteristics of the three varieties shows marked varietal and photoperiodic responses. The variations in dry matter accumulation show that the effects of varieties, photoperiods and age of plants are highly significant. Of these, age appears to be a more potent factor than varieties in so far as dry matter accumulation is concerned. Interaction between age × photoperiod, variety × photoperiod, and variety × age are also significant, indicating thereby that better growth of wheat plants is possible by congenial blending of these controllable factors of growth (Table II).

Taking the interrelation between age and photoperiod into consideration, it is noted that advance in age consistently improved the dry weight of the plant, while increasing photoperiod beyond the normal 12 hours duration is markedly deleterious. That these increases in dry weight in response to age and dry weight decrease in light durations higher than 12 hours are highly significant. At each age plants grown under normal illuminations were consistently better than those grown under 6 or 24 hours photoperiod. Even as early as 45 days photoperiodic effects were found to be highly significant (Table II *b*).

When the overall age values are taken into consideration varieties show highly significant differences under different photoperiods. Under low illumination no marked differences amongst varieties are evident on account of limited period during which synthetic processes leading to dry matter accumulation were allowed to continue. It is only when the illumination period is raised to normal conditions that maximum growth is recorded. Under such conditions NP 165 is distinctly better than C 13 which in its turn is superior to Kubanka (Table II *c*). If the duration of light is further raised to 24 hours duration, a limit is imposed on the growth processes as a result of which imperceptible varietal differences are marked. Several explanations to this depression in growth activity may be given. For instance, excessive illumination may cause solarisation of the chloroplast and inactivate their synthetic efficiency. It may lead to excessive accumulation of meta-

TABLE II

*Dry matter in relation to different factors*

*a. Analysis of variance*

| Serial No. | Due to | D. F. | S. S. | M. S. S. |
|---|---|---|---|---|
| 1 | Samples .. | 5 | 17·55 | 3·51 |
| 2 | Varieties .. | 2 | 694·35 | 347·17 |
| 3 | Photoperiods .. | 2 | 4932·66 | 2466·33 |
| 4 | Age .. | 3 | 15424·00 | 5141·33 |
| 5 | Age × Photoperiod .. | 6 | 5052·76 | 842·13 |
| 6 | Variety × Photoperiod .. | 4 | 955·12 | 238·78 |
| 7 | Variety × Age .. | 6 | 237·93 | 39·66 |
| 8 | Residual .. | 187 | 1881·77 | 10·06 |
| 9 | Total .. | 215 | 29195·14 | |

S.E. per observation = ± 3·2.

*b. Age × Photoperiod interaction*

| Photoperiods (hours) | Age in days | | | | Mean of 72 |
|---|---|---|---|---|---|
| | 45 | 75 | 105 | 135 | |
| 24 .. | 1·1 | 6·7 | 8·6 | 8·6 | 6·3 |
| Normal .. | 0·9 | 10·8 | 20·6 | 38·9 | 17·8 |
| 6 .. | 0·6 | 4·4 | 12·8 | 23·6 | 10·3 |
| Mean of 54 .. | 0·9 | 7·3 | 14·0 | 23·7 | |

TABLE II—(*Continued*)

*c. Variety × Photoperiod interaction*

| Photoperiods (hours) | Varieties | | | Mean of 72 |
|---|---|---|---|---|
| | NP 165 | C 13 | Kubanka | |
| 24 .. | 6·4 | 5·6 | 6·9 | 6·3 |
| Normal .. | 24·1 | 16·6 | 12·8 | 17·8 |
| 6 .. | 11·3 | 10·2 | 9·5 | 10·3 |
| Mean of 54 .. | 13·9 | 10·8 | 9·7 | |

*d. Variety × Age interaction*

| Varieties | Age in days | | | | Mean of 72 |
|---|---|---|---|---|---|
| | 45 | 75 | 105 | 135 | |
| NP 165 .. | 0·9 | 10·3 | 19·1 | 25·5 | 13·9 |
| C 13 .. | 1·0 | 6·8 | 14·4 | 20·9 | 10·8 |
| Kubanka .. | 0·7 | 4·8 | 8·6 | 24·7 | 9·7 |
| Mean of 54 .. | 0·9 | 7·3 | 14·0 | 23·7 | |

S.D. for two means of 18 = 1·05
24 = 0·91
54 = 0·60
72 = 0·53

bolites—products of photochemical reactions, which may interfere with further synthesis of organic compounds. It may also involve high temperature effects under continuous illumination whereby various chemical and enzymatic reactions may be altered. Long photoperiods cut short the dark period so essential for efficient functioning of photosynthetic process in plants and in fact what is attributed to the long photoperiod may as well be due to short dark period of growth. It appears that for balanced vegetative and reproductive growth a certain minimum of this dark phase is absolutely essential.

Varietal growth is also found to be different at successive stages irrespective of the photoperiod under which the plants grow. As early as 45 days in the life-cycle C 13 evinced significantly better growth than Kubanka, but as age advanced NP 165 excelled C 13 and Kubanka. At the final stage, however, differences amongst early and late varieties are less evident (Table II *d*). It appears therefore, that during early stages, growth processes of early and medium varieties proceed at a faster rate, while towards the end Kubanka, the late variety, shows higher efficiency of dry matter accumulation than the early varieties.

## Summary

The effects of three photoperiods of 6 hours, normal and 24 hours were investigated on three varieties of wheat, NP 165, C 13 and Kubanka under Bikaner conditions of soil and climate, in terms of external growth characteristics, dry matter accumulation, flowering time and maturation.

In general plants under normal illumination exhibited better growth than similar plants grown under continuous illumination, which indicates a marked harmful effect on height, leaf number, tillering, number of ears and dry matter accumulation.

Flower initiation was earlier by 22 days in NP 165 under continuous light; earliness by 31 days in C 13 and 64 days in Kubanka was also recorded under similar conditions. Delayed flowering was characteristic in reduced light treatments. Continuous light also reduced maturity period by 25 days in NP 165, by 35 days in C 13 and by 45 days in Kubanka. Final yield of grain was, however, much below that recorded for normal or 6 hours illumination.

Significant interaction between variety and photoperiod, between photoperiod and age and between variety and age indicates that efficient dry matter accumulation requires congenial blending of these conditions of growth.

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