INTRODUCTION TO EXPERIMENTAL WORK

3. 0. 0.

Whole Plant Physiology is an all embracing term which includes the multitude of physiological factors which influence plant development, plant growth and ultimate biological and economic yield. The following study attempts to evaluate comparative physiological development, growth characteristics, and, in view of the common association between semi-dwarf wheat cultivars and nitrogen fertilizer, the response under field and pot conditions to high and low nitrogen applications by selected short stature and standard height cultivars.

The selection of cultivars has been, in the majority of cases, on the basis of performance in a wheat breeding programme in the area. Throughout the following experiments three cultivars are largely recurrent, i.e., Gamut, Chile 1B and Mexico 120. These were selected to represent a typical Australian standard height cultivar, a Mexican semi-dwarf of proven adaptability to the Australian environment and an equally well adapted Mexican dwarf cultivar respectively.

Three major and a fourth miscellaneous series of experiments were conducted in the course of the investigation. These have been titled "Developmental Analysis", "Growth Analysis", "Field Response to Nitrogen Fertilizer", and "Miscellaneous Series", the subject matter of which became pertinent during the course of the three major experiments. To provide continuity each will be described with a Methods, Results and Discussion section. A final Discussion will attempt to integrate the findings of all experiments conducted.

DEVELOPMENTAL ANALYSIS 1967

DEVELOPMENTAL ANALYSIS OF A RANGE OF DWARF, SEMI-DWARF AND STANDARD HEIGHT WHEAT CULTIVARS

4. 0. 0.

The effects of vernalizing temperatures and/or photoperiod on the physiological development of wheat cultivars in commercial cultivation, have been reported by Cooper (1956) in Britain, Riddell and Gries (1958) in the United States of America, Garg and Chinoy (1964) in India, Langer and Khatri (1965) in New Zealand, and Gott (1961) and Marcellos (1970) in Australia. However, apart from references by Syme (1967) and Beech and Norman (1968) to duration of the Seed phase of the dwarf cultivar Mexico 120, comparative information on overall phasic development of short stature wheats and standard height types, appears to be scant in the literature. As developmental data are an integral part of whole plant physiology, and as phase duration may be expected to have a relationship with subsequent grain yield potential, the following analysis of length of phase of vernalized and unvernalized material of a number of representative cultivars was undertaken to determine if major differences existed between the selected short stature and standard height types.

EXPERIMENTAL METHODS

4. 1. 0.

Three vernalization treatments, 0, 28 and 49 days at 34 ± 1.0°F were selected. On the basis of previous experience (Matheson, unpublished data) the three treatments would differentiate the cultivars under study into the categories of spring, intermediate (or semi-winter) and winter, which are used to classify Australian wheat cultivars, (Macindoe and Walkden Brown 1968).

The cultivars for study were chosen to include representatives of currently recommended, standard height cultivars of spring, intermediate and winter type in northwest New South Wales; dwarf and semi-dwarf cultivars of North American, Mexican, Italian and local origin; and certain cultivars of known developmental pattern to serve as controls. The cultivars, their origin, height classification and type are listed in Table 3.

All seed used, with the exception of the cultivars Gaines and Ghurka was grown at Tamworth, New South Wales in 1966 where it was examined for purity and "trueness to type". The seed was well-filled and graded to a uniform size range on a "Clipper" laboratory cleaner and grader.

TABLE 3

CULTIVARS[1] FOR DEVELOPMENTAL ANALYSIS

Cultivar	Country of Origin	Height Classification	Type
Norin 10	Japan	Dwarf	Winter
Gaines	North America	Semi-dwarf	Winter
Mexico 120	Mexico	Dwarf	Spring
Chile 1B	"	Semi-dwarf	Spring
Pugsley Dwarf	"	Dwarf	Spring
Funello	Italy	Semi-dwarf	Spring
8704-70	Australia	Semi-dwarf	Spring
8704-66	"	Dwarf	Spring
Ghurka	"	Semi-dwarf	Spring
Insignia	"	Standard	Spring
Timgalen	"	Standard	Spring
8127	"	Standard	Spring
Controls			
Festival	"	Standard	Spring
Festiguay	"	Standard	Intermediate
Winglen	"	Standard	Winter

[1] Further descriptions of named cultivars are available in "Wheat Breeding and Varieties in Australia" (Macindoe and Walkden Brown 1968).

Vernalization treatments consisted of exposing ten grams of seed of each cultivar, pre-germinated at 70°F for 24 hours, to a temperature of 34 ± 1.0°F in a modified domestic refrigerator fitted with a sensitive thermostat, for 28 (V28) and 49 (V49) days. Throughout the period of vernalization, moisture content of seed was maintained at 50-55% (dry seed basis) by twice weekly weighing and adjustment with distilled water, and adequate aeration of seed was provided. The nil vernalization treatment (VO) was germinated at 70°F for a period of 56 hours to bring to a similar growth stage of coleoptile and seminal root development to the vernalized seed before sowing. All treatments were sown on 12. August, 1967 in the field at Tamworth, New South Wales (Lat. 31°S) in a randomised block design with four replications. Plot size consisted of a 2m. single row into which seedlings were space planted at 12cm. intervals. The sowing date was selected specifically, as experience (Marcellos pers. comm.) had indicated that sowing at this time could be expected to give the best combination of minimum natural field vernalization, and lowest possibility of devernalization by high temperature at this site.

The primary tillers were tagged for subsequent identification, and all observations were thereafter made on the primary tillers of the plants. Sampling for microscopic dissection was commenced when the most vigorous plants had reached the four leaf stage on the primary tiller. This date, 15. September, is designated "A". Sampling was repeated at seven day intervals and the harvests are designated (A + 7) (A + 14) (A + 21) etc.

Five plants were selected at random from each treatment in each replication and after micro-dissection a mean value was determined for stage of development of the apex for that replication. Scoring for stage of development of the apex was made on the basis of photomicrographs (Barnard 1964), the ratings for which are listed in Table 4.

The termination of the Vegetative phase of development was regarded as that time when "double ridges" were visible on the apex (Rating = 4). The end of the Reproductive stage was considered as the point of approximately 60% anthesis (extruded or dehisced anthers) on the primary tiller. Final maturity was considered as that point when the ear and top internode showed no active photosynthetic tissue, and the grain was hard (would not indent when pressed between fingers).

Plots were regularly irrigated throughout the growth cycle to ensure maximum growth. Continuous air temperatures were recorded by a thermograph located in a standard "Stevenson Screen" adjacent to the experiment area. Natural daily photoperiods for the Tamworth area for 1967 were supplied by the Commonwealth Bureau of Meteorology.

TABLE 4

RATINGS FOR STAGES OF DEVELOPMENT IN THE MORPHOLOGY OF THE WHEAT SPIKE (BARNARD 1964)

Rating	Description of Morphology
Figure 1	Apex of Vegetative axis commencing to elongate prior to spike formation.
2	Apex further elongated with younger leaf primordia as crescentic ridges only.
3	Apex much elongated and leaf primordia showing as ridges spikelet primordia almost distinguishable.
4	Spikelet primordia in the axils of the leaf primordia give a "double ridge or ring" appearance.
5	Young spike showing double ridges or spikelet primordia and subtending leaf primordia at the base.
6	Young spike with spikelet primordia developing in acropetal succession.
7	Spikelet primordia with two empty glumes and first lemma developed as ridges.
8	Spikelet primordia showing two empty glumes and first and second lemma.
9	Spikelet primordia viewed without magnification.
(10 (11	Floral parts clearly visible without magnification.

RESULTS

4. 2. 0.

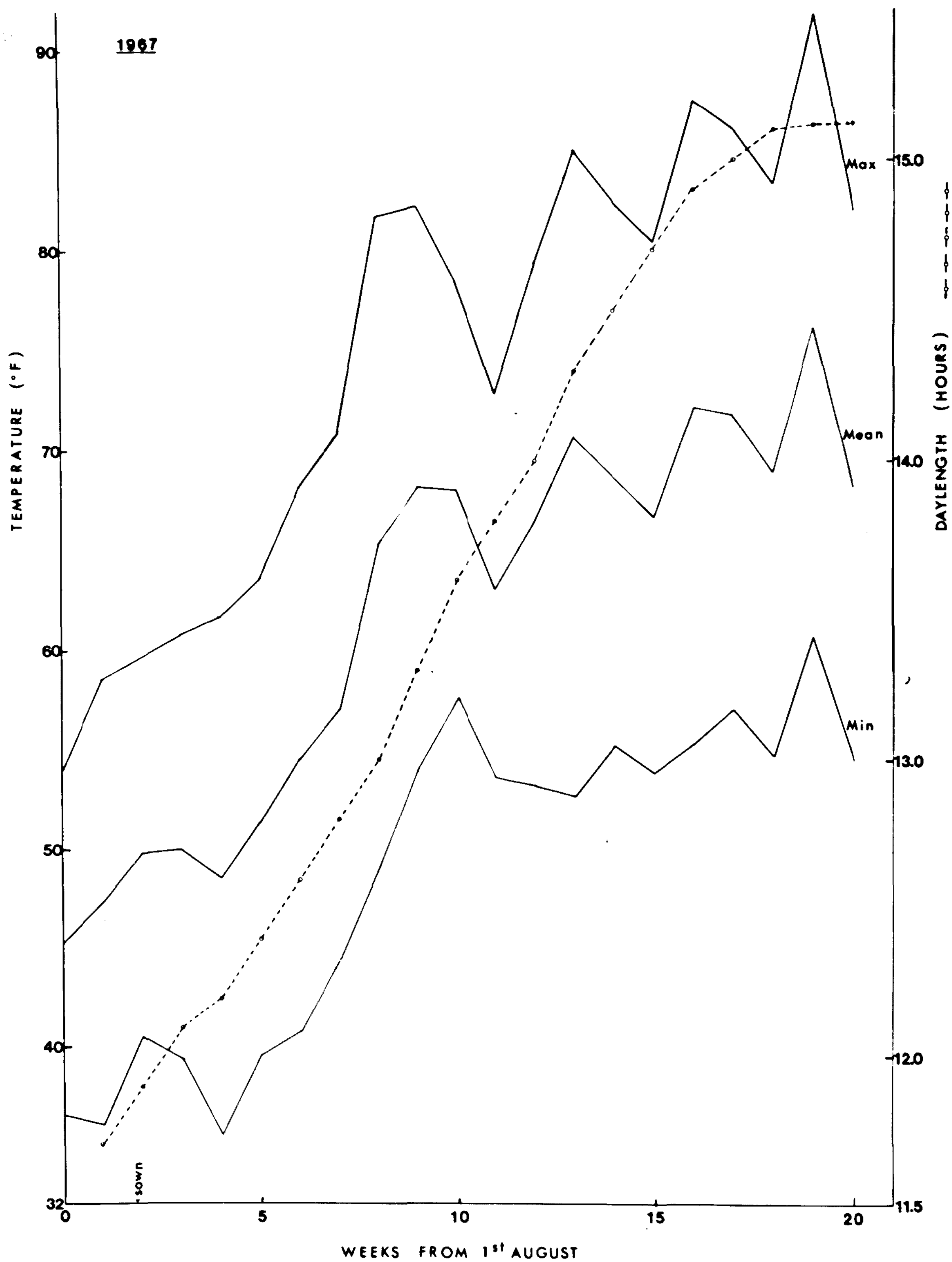
Mean weekly air temperatures measured at the experiment site and the pattern for variation in daily photoperiod for Tamworth during 1967 are shown in Figure 1. At the time of seedling emergence daily photoperiod was approximately 11.5 hours, and mean weekly temperatures were 50.4°F. During the latter stages of grain maturation daily photoperiod had extended to slightly in excess of 15 hours and mean weekly temperatures had risen markedly to approximately 76.0°F. The minimum temperature recorded during the life cycle of the plants was 29.5°F and the maximum 98.0°F. In these data a close association between daily photoperiod and air temperature was apparent (coefficient of correlation = 83.2%) as was indicated by Marcellos (1970) for the same site in 1965.

Seed of the cultivar Gaines was a recent release from Quarantine Sowing and failed to germinate satisfactorily, so was deleted from the trial. In Appendix 1 the Barnard rating for each replication is listed for harvest A through to harvest A + 35 days. Appendix 2 records the mean date of completion of each phase, and the duration in days of the particular phase for each vernalization treatment. The effects of vernalization treatments and the relative phase lengths of the cultivars are illustrated in Figure 2.

FIGURE 1

Temperature and daylength distribution during the period of Developmental Analysis.

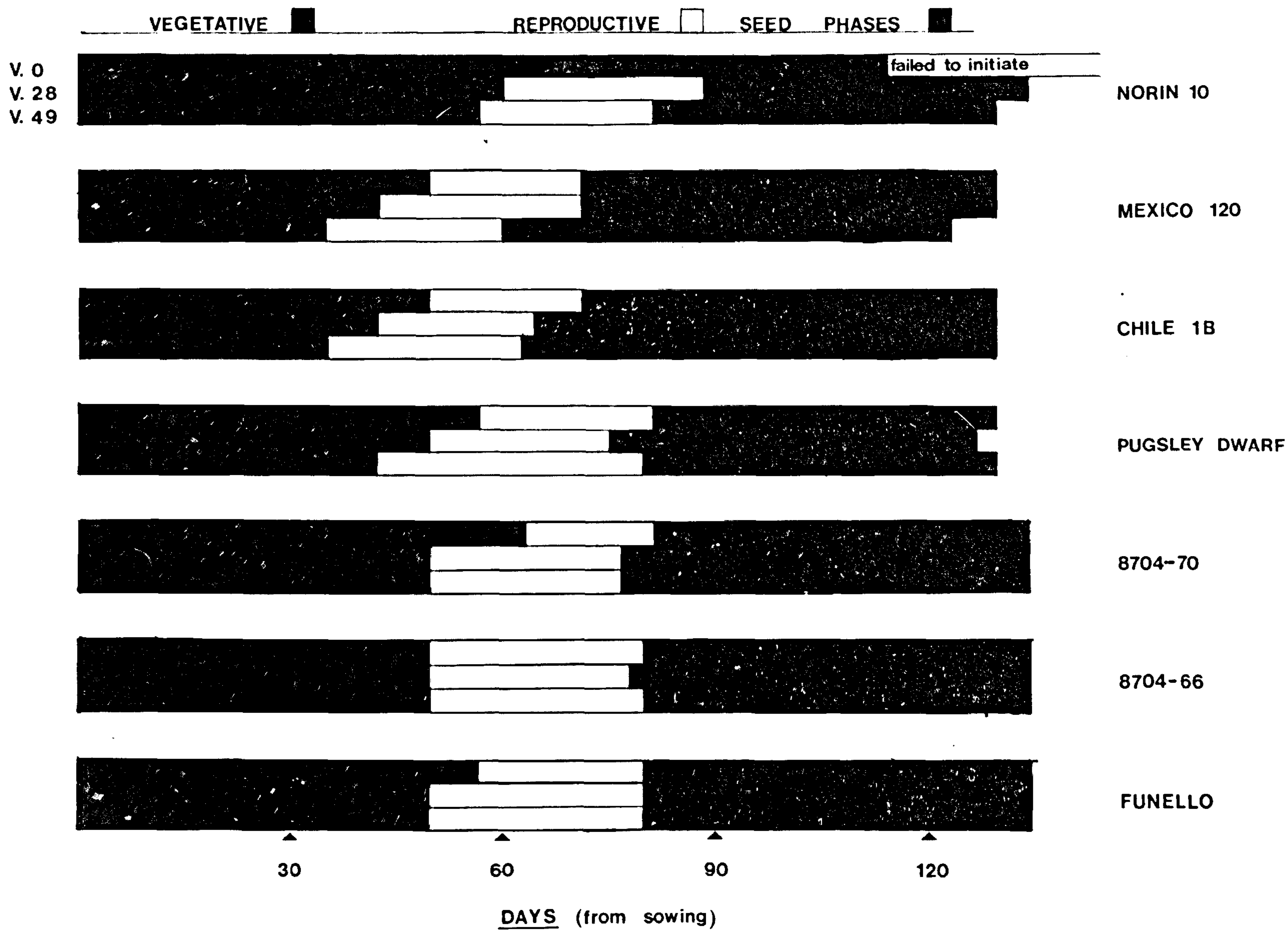
Tamworth - 1967.

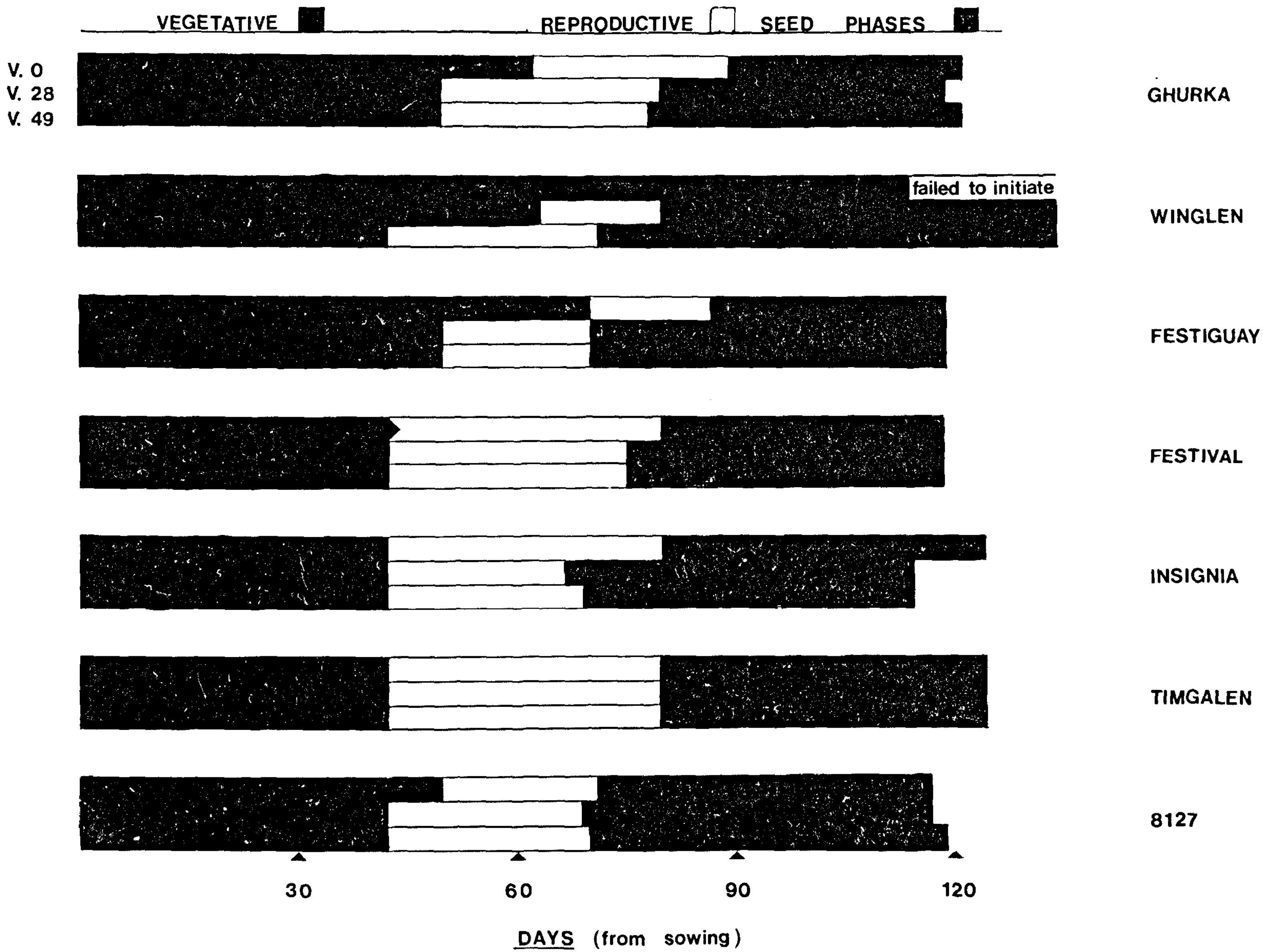


1967
TEMPERATURE (°F)
DAYLENGTH (HOURS)
WEEKS FROM 1st AUGUST
Max
Mean
Min
sown
90
80
70
60
50
40
32
0
5
10
15
20
15.0
14.0
13.0
12.0
11.5

FIGURE 2

Developmental models, indicating the duration of Vegetative, Reproductive and Seed phase at three levels of vernalization for all cultivars examined.


VEGETATIVE
REPRODUCTIVE
SEED PHASES
V. 0
V. 28
V. 49
failed to initiate
NORIN 10
MEXICO 120
CHILE 1B
PUGSLEY DWARF
8704-70
8704-66
FUNELLO
30
60
90
120
DAYS (from sowing)


VEGETATIVE
REPRODUCTIVE
SEED PHASES
V. 0
V. 28
V. 49
GHURKA
failed to initiate
WINGLEN
FESTIGUAY
FESTIVAL
INSIGNIA
TIMGALEN
8127
30
60
90
120
DAYS (from sowing)

Analysis of variance conducted on the data for cultivars which completed the three developmental phases indicated that cultivars and phases were significantly different ($P < 0.001$) - Appendix 3. The interactions treatment x phase, cultivar x phase, and the three factor interaction treatment x cultivar x phase were also significant ($P < 0.001$). Because of the interest in these interactions analyses of variance were conducted separately on data for each phase (Appendix 3b).

Separation of the means of treatments of the twelve cultivars in the Vegetative phase by examination of studentized ranges divided the cultivars into three groups all of which were significant at the 5% level. The groups were (Mexico, Chile, Insignia, Timgalen, Festival and 8127), (Pugsley Dwarf, 8704-66, and Funello), and (Ghurka, 8704-70 and Festiguay) indicating short, medium and long Vegetative phases respectively.

Examination of the two way table for the significant ($P < 0.001$) treatment x cultivar interaction indicated that 8704-66, Insignia, Festival and Timgalen did not respond to treatment. In all the remaining cultivars, duration of the Vegetative phase at nil vernalization was significantly greater [($P < 0.05$), except for 8704-70 and Festiguay where ($P < 0.01$)] than at 28 or 49 days vernalization. The latter two treatments were not significantly different except in Chile 1B, Mexico 120 and Pugsley Dwarf where forty nine days of vernalization was significantly ($P < 0.05$) more effective than twenty eight days treatment.

In the Reproductive phase treatments and cultivars were significantly different ($P < 0.001$) and the treatment x cultivar interaction was significant ($P < 0.001$). Examination of the means of cultivars by means of studentized ranges established four groups of cultivars which were significant at the 5% level. These were (Festiguay), (Chile 1B, Mexico 120, 8704-70 and 8127), (Funello, Ghurka, Timgalen, 8704-66, Pugsley Dwarf and 8704-70), and (Festival). The short mean Reproductive phase of Festiguay (i.e., 19 days) was noteworthy in comparison to that of Festival (i.e., 34 days). Examination of the two-way treatment x cultivar interaction table indicated that the behaviour was variable between cultivars and no general patterns could be found. Interpretation of the response in this phase was confounded by different temperature regimes between cultivars, within cultivars but between treatments, and by varietal differences in response to temperature - the result of different times of entry to, and completion of phases for cultivars, and for different treatments.

In the Seed phase, examination of the means of cultivars by means of studentized ranges divided these into six groups which were significant from each other at the 5% level. In order of increasing phase duration these were (Ghurka), (Festival, Festiguay, Insignia), (Timgalen, 8127), (Pugsley Dwarf), (Funello, 8704-66, 8704-70, Mexico 120), and (Chile 1B). In the ranking, all standard height cultivars occur in groups one, two and three, with all short stature wheats in the following groups. Again examination of the two factor interaction table for treatment x cultivar indicates irregularities in response pattern between cultivars and within treatments. The basis for these irregularities was considered to be the same as that for those in the

Reproductive phase.

To enable comparison of relative phase length of cultivars these are tabulated separately (Table 5) at the V49 treatment which for all cultivars other than Norin 10 enabled normal progression through the life cycle without vernalization acting as a restrictive developmental block.

TABLE 5

PHASE LENGTH OF CULTIVARS AT TREATMENT V49

Cultivar	Vegetative Phase	Reproductive Phase	Seed Phase
All Dwarf and Semi Dwarf			
Norin 10	56	25	>48
Mexico 120	35	25	63
Chile 1B	35	27	67
Pugsley Dwarf	42	37	50
8704-70	49	27	58
8704-66	49	30	55
Funello	49	30	55
Mean	45.0	28.7	56.6
All Standard Height			
Insignia	42	26	46
Winglen	42	29	63
Festiguay	49	21	48
Festival	42	33	43
Timgalen	42	29	45
8127	42	28	48
Ghurka	49	28	44
Mean	44.0	27.7	48.1

5% Studentized Range - Cultivars = 3.03 (14 means)

" " " Phases = 0.98 (3 means)

Source	df	Mean Square	F	Significance
Replicates (R)	3	10.10	2.14	NS
Phases (P)	2	8674.86	1833.52	***
Cultivars (V)	13	76.07	16.08	***
PV	26	199.49	42.16	***
Error	123	4.73	-	

SE (P) = 0.291

SE (V) = 0.627

In these data the duration of the Seed phase for Norin 10 could not be defined accurately because, at the termination of the experiment the heads on the primary tiller of this cultivar remained green but were dehydrated and were obviously not actively photosynthesising. This condition was interpreted as premature death of inflorescence tissue as opposed to ripening. For this reason the duration of the Seed phase for Norin 10 is presented in the Table 5 as >48 days although a phase length of 48 days was used in the analysis of variance. In the Table the data are divided into the two categories of short and standard height. The mean phase durations are similar in both the Vegetative and Reproductive phases. In the Seed phase however, the mean duration for the short stature types is longer than that of the standard height types. The variance for the analysis was subsequently partitioned into dwarf and standard types. The (Dwarf v. Standard) x phase interaction was found to be significant ($P < 0.001$) indicating different effect of phase on stature. Examination of the Studentized Ranges involved showed that dwarf and standards were not significantly different in Vegetative and Reproductive phases, but the Seed phase was significantly longer ($P < 0.01$) in the short stature types. Although Ghurka was included in the trial as an Australian short stature type its height in this trial and its developmental pattern recommended its inclusion with standard rather than short stature types.

In Table 6 the arithmetic means of Norin derivative short stature wheats in each phase are compared with those for the "Spring type" Australian standard height wheats in the experiment at treatment V49 days.

TABLE 6

COMPARATIVE PHASE LENGTHS OF NORIN DERIVATIVE SHORT STATURE AND AUSTRALIAN STANDARD HEIGHT SPRING WHEATS

Cultivar	Vegetative Phase	Reproductive Phase	Seed Phase
Norin Origin Short			
Norin	56	25	>48
Mexico 120	35	25	63
Chile 1B	35	27	67
Pugsley Dwarf	42	37	50
8704-70	49	27	58
8704-66	49	30	55
Mean	44.3	28.5	56.8
Australian Standard Height ("Spring")			
Insignia	42	26	46
Festival	42	33	43
Festiguay	49	21	48
Timgalen	42	29	45
8127	42	28	48
Ghurka	49	28	44
Mean	44.3	27.5	45.3

5% Studentized Range - Cultivars = 3.09 (12 means)

" " " Phases = 1.11 (3 means)

Source	df	Mean Square	F	Significance
Replicates (R)	3	13.78	2.66	NS
Phases (P)	2	6947.44	1340.55	***
Cultivars (V)	11	65.22	12.58	***
PV	22	201.07	38.80	***
Error	105	5.18		

SE (P) = 0.328

SE (V) = 0.657

The similarity between the two groups in mean duration of Vegetative and Reproductive phases is again apparent and the duration of Seed phase for Norin derivative wheats after partitioning of the above variance was significantly longer ($P < 0.01$) than for Australian "spring types".

In Table 7 observed and calculated lengths of both Vegetative and Reproductive phases are recorded for the cultivars, Festiguay, Festival, Winglen and Mexico 120. The calculated values are derived from the simulation equation of Marcellos (1970) of the form.

$$y = b_o + b_1 (1/X_1) + b_2X_2,$$

where y is the length in days of the phase in question, X_1 is the mean daily temperature experienced in the field during the phase, and X_2 is the corresponding value of mean daily photoperiod. The constants b_o, b_1 and b_2, the intercept and partial regression coefficients respectively are those determined by Marcellos (1970) for these cultivars. To the calculated values for the Vegetative phase ten days have been added to allow comparison between "brairding" (when coleoptiles of 50% of plants in the row were visible) to initiation used by Marcellos and germination to initiation used by the author to define the Vegetative phase.

Comparisons of observed and calculated lengths of the Seed phase have been omitted due to major differences in definition of the phase end point, Marcellos (1970) having used the late dough stage of grain development as the termination point of the phase.

TABLE 7

CALCULATED AND OBSERVED PHASE LENGTHS OF SOME CULTIVARS AT TREATMENT V49 (days)

Cultivar	Vegetative Phase		Reproductive Phase	
	Calculated	Observed	Calculated	Observed
Festiguay	44	49	31	21
Festival	45	42	29	33
Winglen	44	42	31	29
Mexico 120	32	35	28	25

For the cultivars Festival, Winglen and Mexico 120 a satisfactory level of agreement was found between calculated and observed values for duration of both phases. Festiguay in these data, however, does not fit the model of Marcellos (1970), exhibiting five days difference in the Vegetative phase and ten days difference in the Reproductive phase, between observed and calculated values.

DISCUSSION

4. 3. 0.

VERNALIZATION

4. 3. 1.

The cultivar Norin 10 is a Japanese winter wheat with a substantial vernalization requirement. As a result of the comparatively late sowing date (12. August), plants from the V0 treatment failed to receive sufficient field vernalization to achieve competence, and in consequence did not produce heads by the termination of the experiment. The extremely late anthesis date recorded for this cultivar indicated that even at treatment V49 the vernalization requirement was not entirely saturated under the conditions of the experiment. Gitoh (pers. comm.) considers that this cultivar has in fact a vernalization requirement in excess of 60 days.

Brevor, the second parent of the foundation material for all the Norin derivative, short stature wheats is also classified by Reitz (pers. comm.) as a strongly winter type cultivar. In consequence it is reasonable to expect some degree of vernalization response in cultivars such as Mexico 120 and Chile 1B, which are closely related to the Norin 10 x Brevor 14 parental material, and which do exhibit significant acceleration of initiation as a result of vernalization. The response is, however, of lesser magnitude than the winter ancestor Norin 10, but is sufficient to explain the long Vegetative phase of development in these cultivars in summer sowings (Matheson, unpublished data) when temperatures are above those necessary for field vernalization.

The semi-dwarfs, Pugsley Dwarf and 8704-70 which are further removed in parental derivation from the line Mexico 120, have apparently retained much of the vernalization response of the Mexican parent. Conversely, the line 8704-66 which is a partial backcross of the pedigree, 8704^3 x Mexico 120 exhibits complete absence of a vernalization response. Lack of response qualifies this line for inclusion in a rather restricted class of wheats in Australia which do not respond to vernalization. To the knowledge of the author it is the first observation of a Norin-derivative, semi-dwarf wheat with a nil response to vernalization, although Syme (1968) has since reported a recent introduction from Mexico which also has a nil vernalization response.

The cultivars, Ghurka, Festiguay and Funello exhibit moderate response to vernalization, and would fall into the Australian classification of intermediate types. The cultivars Insignia, Festival, Timgalen and the line 8127 made up the group (together with 8704-66) of having either a slight, [in which field temperatures may provide saturation] or nil vernalization requirement. In this grouping the data derived from the trial for two cultivars were of particular interest at the time. Firstly, the cultivar Festival which is commonly used by Australian developmental physiologists (Gott 1961) as a control for nil vernalization response gives indication of slight response in these data (Appendix 2). Such a reaction for Festival is unusual, but had been encountered previously by Marcellos (pers. comm.) who gives a frequency of 6% for this type of reaction; this may indicate that in Festival the character is either genetically unstable or not "fixed". Secondly, the cultivar Timgalen, which was named and released for commercial cultivation during the progress of this work, was previously considered to have a strong developmental block, in the form of a substantial vernalization requirement.

No explanation for the extension of the Reproductive phase for the cultivar Insignia at treatment V0 in these data can be suggested.

4. 3. 2.

Comparisons of phase durations for cultivars common to these and the data of Marcellos (1970) who also used a V49 treatment for the same site in 1965 indicates some differences. Marcellos (1970) determined the length of the Vegetative phase from the point of "brairding", as opposed to the time of sowing used by the author. This would account for a difference of approximately 10 days at the prevailing soil temperatures (Mean for August at 2.5 cm. soil depth = 52.4°F). When this interval is added to the Vegetative phase lengths recorded by Marcellos (1970) differences between the two sets of data for this phase are within the range of 2-8 days (Table 8).

TABLE 8

COMPARATIVE DURATION OF DEVELOPMENTAL PHASES IN AN AUGUST SOWING AT TREATMENT V49 (DAYS)

Cultivar	Year	Phase length (days) Vegetative	Reproductive	Seed	Total
Festiguay	1965*	41 (1)	34	25 (3)	100
	1967	49	21	48 (4)	118
Winglen	1965	44 (1)	33	- (2)	- (2)
	1967	42	29	63 (4)	134
Mexico 120	1965	27 (1)	34	27 (3)	88
	1967	35	25	63	129
Festival	1965	44 (1)	32	27 (3)	103
	1967	42	33	43 (4)	128

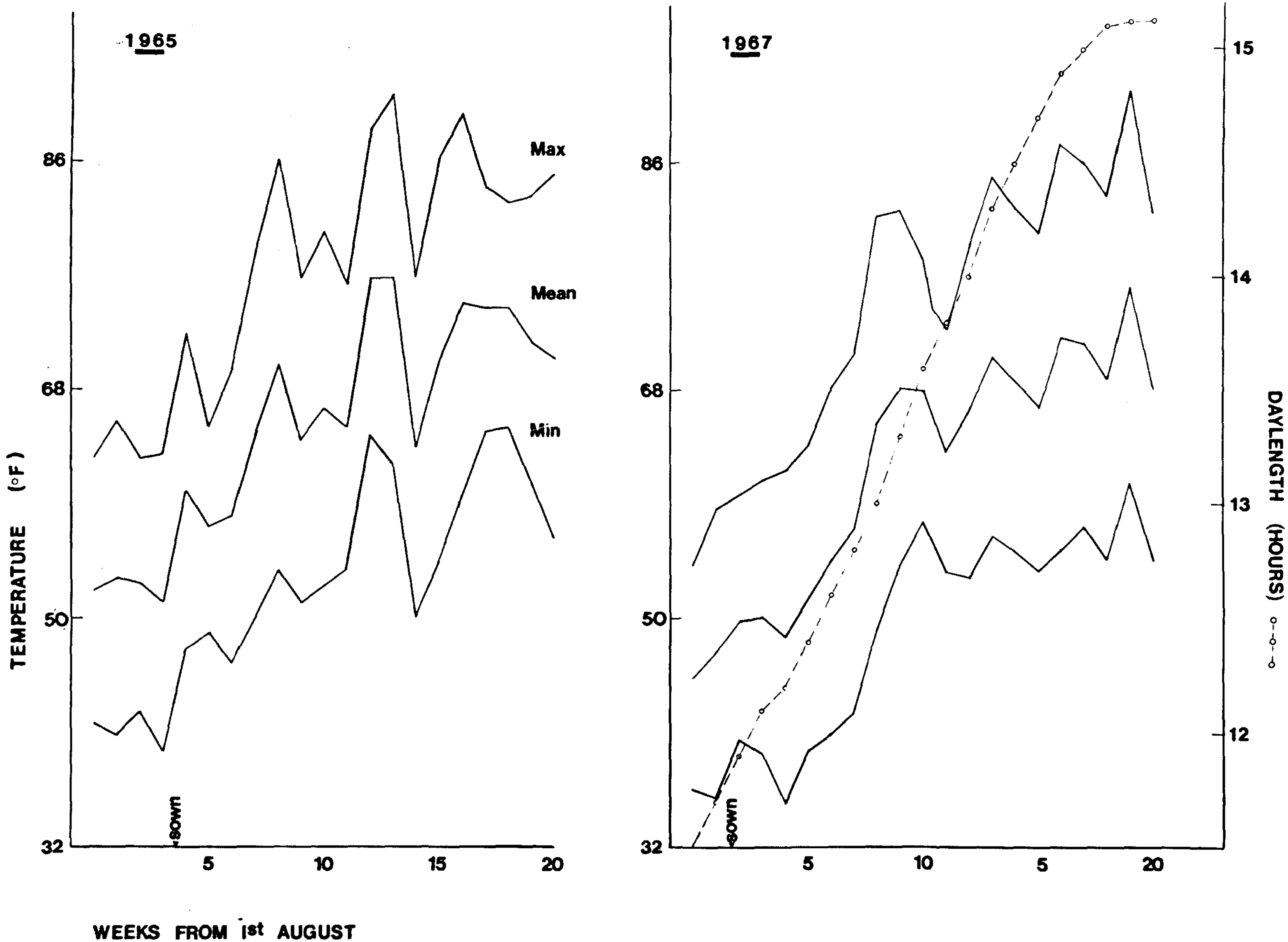
* 1965 data recorded by Marcellos
(1) Duration after adding 10 days for germination to brairding
(2) No recording
(3) Phase end point = late dough stage
(4) Phase end point = grain hard

However, major variation (e.g., Festiguay) does exist between the two sets of data in the duration of subsequent phases. As length of daily photoperiod in 1965 when the data of Marcellos (1970) were recorded, and in 1967 differs to a very minor extent, (the result of slightly different sowing dates (Figure 3) and as supplemental irrigation was applied in both years, the variation in Reproductive and Seed phases between the two sets of data can be interpreted as the result of different temperature distribution pattern between the two years. Figure 3 illustrates that this was, in fact, the situation. In 1965 early spring temperatures (i.e., Vegetative phase) were high, whereas in mid spring (i.e., Reproductive phase) mean temperatures were generally below those recorded in 1967. In late spring and early summer (i.e., Seed phase) mean daily temperatures as well as minimum temperatures in 1965 generally exceed those recorded in 1967.

It is of interest to compare the two sets of data for the cultivar Festival, which is the only common cultivar without a significant vernalization response. Despite substantial differences in temperature distribution between 1965 and 1967 the duration of the Juvenile phase (from germination to anthesis) for this cultivar is almost identical in the two sets of data. The marked variation in the duration of the Generative phase (from anthesis to maturity) between 1965 and 1967 (Table 8) is attributed to higher mean maximum and minimum temperatures in 1965, particularly in the earlier part of the phase which resulted in curtailment of grain development. The duration of the Generative phase recorded in 1965 is considered by this author to be abnormally short, even recognising different phase end points

FIGURE 3

The comparison of temperature data for the August-December period between years 1965 and 1967.


1965
1967
Max
Mean
Min
86
68
50
32
5
10
15
20
5
10
5
20
15
14
13
12
sown
sown
TEMPERATURE (°F)
DAYLENGTH (HOURS)
WEEKS FROM 1st AUGUST

between the two sets of data. The curtailed Seed phase in 1965 is indicative of premature ripening resulting from high temperatures as opposed to normal physiological ripening of grain.

Comparison of the cumulative sums of weekly mean temperature over each developmental phase for the cultivar Festival for the years 1965 and 1967 (Table 9) indicates a lack of similarity in the Vegetative phase but a striking similarity between years in both Reproductive and Seed phases.

TABLE 9

SUM OF WEEKLY MEAN TEMPERATURES (°F) IN DEVELOPMENTAL PHASES FOR THE CULTIVAR FESTIVAL

Phase	1965 Minimum	1965 Maximum	1965 Mean	1967 Minimum	1967 Maximum	1967 Mean
Vegetative	146	320	233	78	226	152
Reproductive	140	267	203	156	286	221
Seed	150	294	222	148	299	239

Despite the difference of twenty five days between years in the Seed phase, the summations of minimum, maximum and mean weekly temperatures for 1965 and 1967 (Table 9) are remarkably similar in both Reproductive and Seed phases. The fact that temperature summations in the Vegetative phase are not similar may indicate that prior to initiation the rate of development of this cultivar is not responsive to temperature acceleration but thereafter becomes highly responsive. This response to high temperature is indicated by Marcellos (1970) for the sub-phase, ear peep to anthesis, and warrants further investigation over the broad developmental period from ear peep to maturity.

The similarity in duration of Seed phase for all Australian spring types in these data support the findings of Marcellos (1970), that "all varieties were similar in their post anthesis development". This similarity of Seed phase duration may be expected when they have each been selected in an environment which imposes severe climatic restraints in the period of grain development. However, when comparison is made between the Australian spring types and winter types, e.g., Winglen, or imported wheats, e.g., Funello and Mexico 120, differences in the duration of the Seed phase are apparent.

That the cultivars Festiguay and Ghurka at nil vernalization treatment are able to condense Reproductive and Seed phases after a prolonged Vegetative phase and ultimately produce a satisfactory grain sample, indicates that the latter two phases of development in Australian cultivars may be more responsive to high temperature acceleration than is the case in some imported cultivars. Festiguay is the product of a developmental breeding programme the objective of which was to delay initiation to minimise frost damage. To ensure against unfavourably late maturity, selection for condensed Reproductive and Seed phases was attempted (Matheson 1963). This adaptive ability is well illustrated in the data for Festiguay (V0). As such this constitutes a very different developmental model of a wheat plant to that demonstrated in these data for the Norin derivative, short stature wheats which characteristically exhibit a long Seed phase as measured on the primary tiller, and may explain the failure of Festiguay to fit the Marcellos model in the Reproductive phase. Failure of the cultivar Norin 10 at V28 and V49 to mature normal grain at >46 and 48 days duration of Seed phase under the conditions of the experiment prevents the direct relation of the long Seed phase with the Norin 10 parent and suggests the possibility that this characteristic in lines derived from this cross may owe part at least of its source to the other parent, Brevor 14. As with vernalization response however, the characteristic long Seed phase appears to be retained in proportion to the degree of genetic dilution of the original parental material. Unless plant breeders specifically select for long duration of this phase it is most probable that the original developmental model of the early Mexican short stature wheats, as represented by Mexico 120 and Chile 1B, will be changed significantly, and some physiological yield attributes of this model may be lost.

Extrapolation of these data derived from a single late sowing without concomitant photoperiodic response data, to the general field situation of the wheat-belt is not justified. However, some generalisations appear permissible. As a possible yield mechanism the duration of the Seed phase in itself is obviously not all important, as indicated by the fact that the cultivar Winglen, which is not a high yielding cultivar, has at treatment V49 the longest of Seed phases in the data. The importance of a long Seed phase appears to be its association with relatively short Vegetative and Reproductive phases, to enable grain development to proceed under more favourable environmental conditions. The cultivars Mexico 120 and Chile 1B appear unique in this characteristic, amongst these under test, and in the data have entered the Seed phase only shortly after Festiguay has achieved competence. Under field conditions in the Australian wheat-belt, cultivars of this type of developmental model would have a distinct advantage in that, in the absence of frost damage, mean temperatures through the Seed phase would be more favourable for grain filling and respiration losses could be expected to be less. Conversely, grain protein levels may also be expected to be generally lower.

On the basis of developmental pattern the cultivars Ghurka and Funello, obviously fall into classes different from that of Mexico 120 and Chile 1B. Funello has, in fact, an unusual pattern of phasic development, characterised by an exceptionally long Vegetative phase coupled indirectly to a moderately long Seed phase. The cultivar Ghurka, although characterised by significant vernalization response, appears to closely resemble the very characteristic developmental model of the Australian spring wheat types Festival, Timgalen, Insignia and line 8127. The prominent features of this model, that appears to have originated with Farrer wheats - the first cultivars bred in Australia - and the model which has been rigidly adhered to by the majority of subsequent plant breeders, are relative uniformity of phase duration, coupled with a short Seed phase. Such a developmental pattern has been necessitated by the danger of frost injury to cultivars in which ear emergence occurs early in the spring, and by the need for a short Seed phase in an environment of rapidly rising temperatures and moisture stress. Such a development pattern constitutes an admirable "fit" of germplasm to environment but is not conducive to high grain yield under more favourable conditions. Similarly, the long Seed phase of the winter type cultivar Winglen may well explain its inability to "finish" under adverse conditions.

When the average duration of phases for the Norin derivative short stature cultivars at the 49 days of treatment level is compared in this trial to that for the standard height spring cultivars (Table 6) several points of interest become apparent. Firstly, the average duration of the Vegetative and Reproduction phases is strikingly similar in these data for both Norin derivative and Australian spring standard height types. As the Mexican short stature wheats featured Australian short day types among their pro-genitors, it appears that some characteristics of the "Australian developmental model" have been retained.

Secondly, the average duration of the Seed phase is longer for the Norin derivative semi-dwarfs than for the standard height spring types. The mean duration for the cultivars Mexico 120 and Chile 1B is, in fact, approximately 16 days longer. The importance of the relative period of onset of the Seed phase and its duration in short stature wheats, appears to be emphasised by the ability of semi-dwarfs to express very high grain yields under favourable conditions of moisture and temperature in the Seed phase, (e.g., Mexico and the Pacific Northwest) and their apparent inability to express this superiority over standard height types under harsher environmental conditions, (Heyne pers. comm.)

SUMMARY

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The data derived from this developmental analysis serve to elucidate several features.

1) Although a strong vernalization response was evident in the original parental material Norin 10, and has in part been perpetuated in the early Mexican cultivars, this is not a prerequisite of short stature wheats; and could therefore be in danger of being totally eliminated from more recent, short stature wheats of Norin-derivative origin, under generation cycling between winter and summer sowings commonly employed in Australian plant breeding programmes.

2) The cultivars, Mexico 120 and Chile 1B, have a characteristic developmental pattern which differs considerably from that of the other wheats in the experiment, in the short duration of the Juvenile phase (germination to anthesis) and longer duration of the Generative phase (anthesis to maturity).

3) The cultivars, Insignia, Ghurka and Funello, although of relatively short stature, represent different patterns of development to those of the Mexican semi-dwarfs in this experiment.

4) It may be speculated that the time of onset and the duration of the Seed phase of development for the cultivars, Mexico 120 and Chile 1B, could be part, at least, of the physiological basis of the reputed higher yield potential of these cultivars. Conversely, together these may provide a valuable selection index for potentially high yielding short stature wheats in segregating populations.