THE PERFORMANCE OF SOME CULTIVARS OF COMMON WHEAT (*TRITICUM AESTIVUM* L.) AT KPONG (GHANA)

By

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JUNE, 1980.

DEDICATED TO

SENA

AND IN MEMORY OF

EBENEZER KWAO LAMPTEY

(MY LATE DAD)

DECLARATION

I do hereby declare that, except references to other people's work which have been duly cited, this work is the result of my own original research and that this thesis either in whole or in part has not been presented for another degree elsewhere.

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ABSTRACT

The performance of 16 cultivers of common wheat (*Triticum aestivum* L.) was studied at Kpong in 8 monthly plantings to ascertain the possibility of growing wheat on the Accra Plains. The characters studied were: tillering rate, fertile tillering percentage, number of leaves per plant at anthesis, number of days to anthesis, number of days to maturity, plant height, lodging and seed quality scores, total dry weight per plant, grain yield per plant, grain yield per plot, number of seeds per spikelet, number of spikelets per plant and 1,000 - grain weight.

By means of an analytical procedure for determining adaptation based on economic yield (the regression technique), a numerical grading of the planting dates showing their favourability to wheat performance was obtained. Meteorological data collected during the study was also used to adduce possible reasons for the relative performance of the crop over the seasons.

Apart from observed significant differences among cultivars in respect of the characters studied, cultivars showed marked differences in their adaptability as seen in the highly significant interactions obtained between planting dates and cultivars. In addition, the slight seasonal variation in climatic factors appeared to have marked effects on the performance of the crop.

The June planting was observed as the most favourable to the crop followed by that of May. The least favourable was the September planting. The three most adaptable cultivars, all of Canadian origin, were 7438 - X, 7423 - K4 and 7438 - D (in that order).

It is concluded that heat was the factor most limiting to wheat performance on the Accra Plains and that the crop could grow profitably if less heat-sensitive cultivars could be selected, and the most favourable planting periods determined, through similar studies in other locations of similar or cooler climate.

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INTRODUCTION

Wheat (Triticum spp.) has served as an important source of food since ancient times. It is generally believed that prehistoric man cultivated a wheat-like plant from which he ground and baked the grains. Today, millions of people derive their livelihood from wheat and it forms an important part of the daily diet of millions more, often preferred to any other grain as human food. The approximate proportions of the total world production of wheat grain used for different purposes is as follows: Human consumption 74%; seed 11%; feed for livestock 14%; industrial use 1%. Wheat straw is usable as feed and litter for livestock and as a protectant against soil erosion. Industrially, it is used for the manufacture of straw board, building board, paper and other pulp products. The average composition of the whole grain is: Protein 12%; fat 2%; carbohydrates (starches and sugars) 69%; crude fibre 2%; minerals 1.5%; vitamins (particularly B vitamins) a fraction of 1%; water 13%.

During the last two decades, there has been a great increase in the consumption of bread (one of the chief products of wheat) in the tropics, where the food is non-indigenous. Initially, this applied to the higher income groups in these countries. Today, it has lost its status symbol, having become more and more a part of the daily diet of the lower income groups as well. As a result, wheat-importing countries like Ghana are finding it increasingly difficult to cope with the foreign exchange demands in return for wheat and its products to meet their growing demand. Ghana for example has had to settle, on the average, the foreign exchange equivalent of about ₵44 million annually over the last three years, being the cost of unmilled wheat alone. The annual average tonnage of wheat or flour imported into the country in the late 1970's was more than double that of the early 1960's. This trend is likely to continue.

As a measure to reduce the importation of wheat, composite flours are being tried in some countries but this is yet to catch on with the consumer who is used to bread from wheat flour. Another means of reducing wheat imports has been the cultivation of the crop locally, where this is possible.

Recent interest in research into growing wheat in Ghana is in line with attempts by some non wheat-producing countries. This thesis studies the growth, development and yields of several wheat cultivars selected for their reportedly good performance in the tropics. It also attempts, from the measured responses, to find the physiological basis underlying their performance with the view to establishing whether it is possible to grow wheat on the Accra Plains and the Lowland Tropics in general.

II

REVIEW OF LITERATURE

1. Origin, Early History and Dissemination

The ancestors of common or bread wheat (*Triticum aestivum* L. em Thell) originated from Western Asia, either in Mesopotamia (now Iraq) or in the highlands of Ethiopia (Peterson, 1965; Janick *et al*, 1969; Martin and Leonard, 1970; Agric. Canada, 1977).

The history of the plant can be traced back 10,000 to 15,000 years ago. The earliest traces of the plant were found in the ruins of the Swiss lake dwellers of that age. As far back as Old Testament times, some 4,000 years ago, wheat was an important crop. In those days wheat was called called "corn" as it was referred to in the story of Joseph who stored "corn" in Egypt in the familiar biblical account (Agric. Canada, 1977).

In an attempt to increase world production, the wheat plant has been introduced into areas with environments quite different from that of its origin. As Anderson (1973) states, "the record or near record crops of the developing countries in the tropic and subtropic areas has been the only saving feature preventing starvation on a massive scale." Thus wheat has become an international crop. Its dissemination has been made possible through breeding and selection from the originally temperate-adapted species. The objective has been to increase productivity, enhance stability and increase physiological efficiency of the plant while improving grain quality, under various environmental conditions (Creech and Reitz, 1971).

According to Purseglove (1975) wheat was first domesticated in the Middle East from where it spread quickly throughout Asia and Europe. It reached the Americas in the sixteenth century and has now spread widely throughout all the temperate regions of the world and to the higher altitudes in the tropics. Lord Delamere is reported to have successfully introduced wheat into Kenya early this century. Andrews (1968; 1969) indicates that wheat has been growing in Nigeria for centuries, but up to 1960 on a marginal scale confined to the Sahel and Sudan zones (12°- 14°N) and on the Mambilla plateau in a more southerly location.

Although imports of flour into Ghana (then Gold Coast) began as early as 1529 when the Portuguese were said to have provided each person in Elmina fort with a daily issue of four loaves of bread (Youngs, 1972), it is doubtful if there were any attempts to cultivate the crop in Ghana until 1964 when a number of experiments were conducted on wheat (Mensah, 1979).

2. Taxonomy

The term wheat refers to a number of species, belonging to the genus *Triticum*, which form a polyploid series with 14, 28 and 42 chromosomes (Peterson, 1965). All members of the genus *Triticum* are annual grasses belonging to the tribe *Triticeae* in the subfamily *Pooideae* of the family *Gramineae*.

In this genus there are three different genomes designated A, B and D which through hybridization and chromosome doubling have given rise to the cultivated wheats. The wild species *T. boeoticum* (2n = 14; A genome), *Aegilops speltoides* (2n = 14; B genome), *T. dicoccoides* (2n = 28; AB genome) and *Aegilops squarrosa* (2n = 14; D genome) are believed to be the ancestors of the cultivated wheat species (Peterson, 1965; Purseglove, 1975). The contributions of these wild ancestors have been summarised by Purseglove (1975) as shown in Figure 1.

Common or bread wheat (*T. aestivum*), Durum wheat (*T. durum*), Spelt wheat (*T. spelta*) and Emmer wheat (*T. dicoccum*) are examples of important wheat species. Bread wheat, known botanically as *Triticum aestivum* L., is of concern in this project. This species is by far the most important due to its high gluten content which confers on its flour the property of trapping the carbon dioxide produced by fermenting yeast, so that upon leavening and baking, a characteristic porous bread is obtained.

3. Botany

Wheat is a free tillering annual. On the average it produces 4 or 5 tillers per plant but under typical crowded field conditions, only 2 or 3 tillers are produced. Under very favourable conditions, however, it can produce up to 40 or 50 tillers. Each normal tiller produces leaves and terminates in a head or spike. In the field it reaches 0.3m – 0.9m,

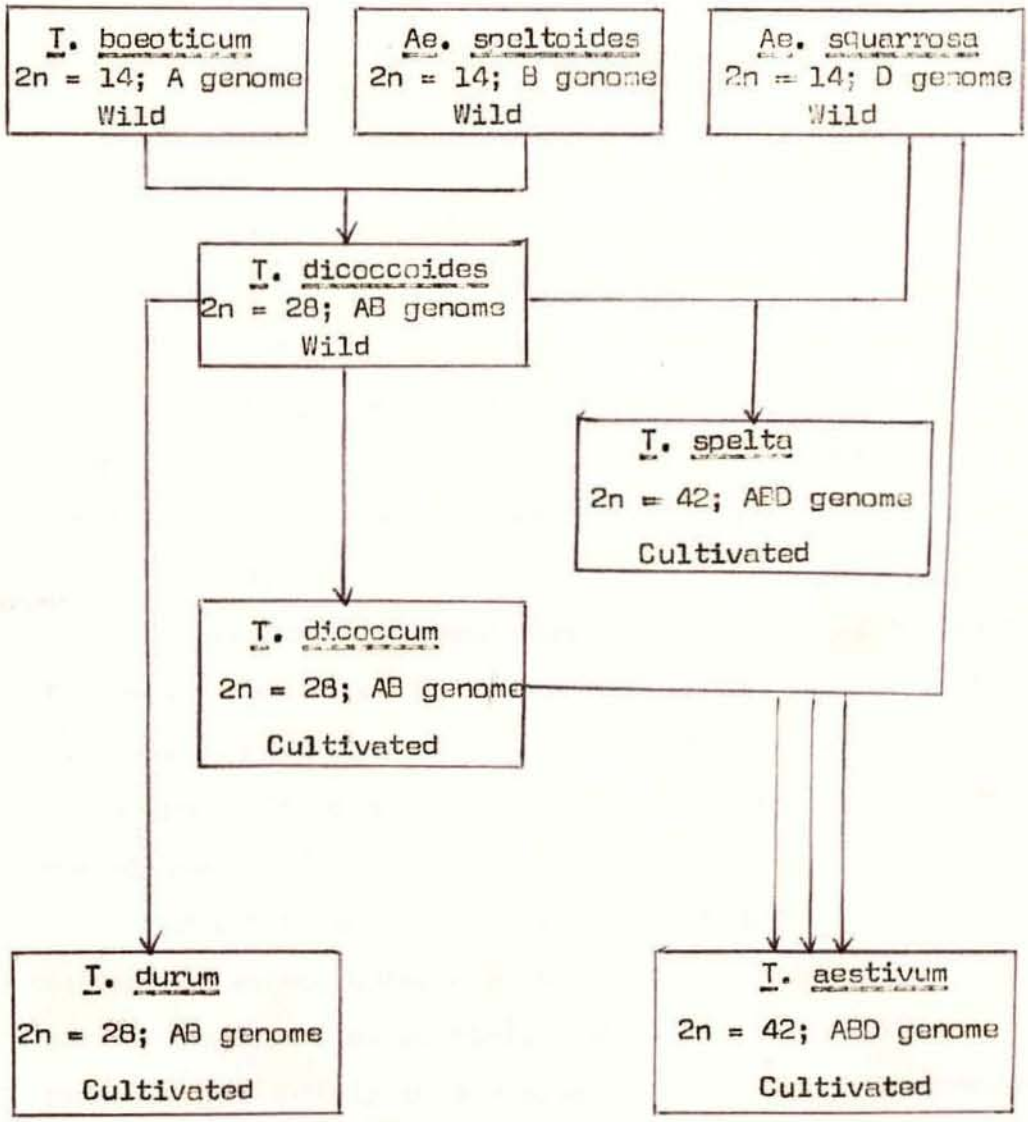


FIG. 1 Derivation of the cultivated wheats.

(Purseglove, 1975)

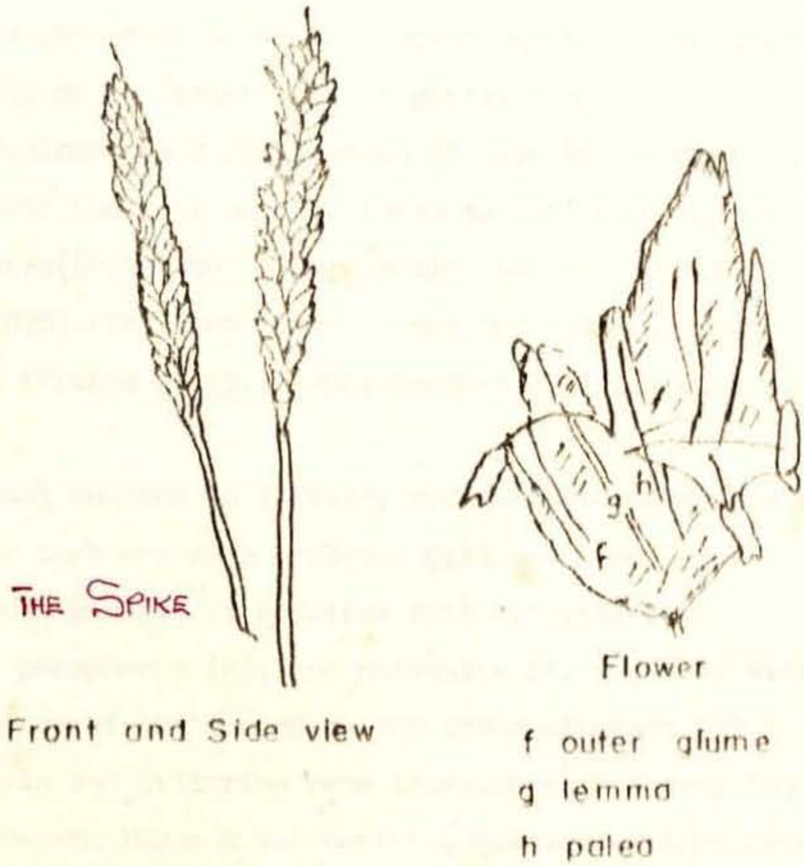
while in the greenhouse it could reach 1.5m in height (Martin and Leonard, 1970; Agric. Canada, 1977).

Seed germination is hypogeal with 2 types of roots; about 3 to 6 seminal roots followed by adventitious roots. Growth habit may be termed winter, intermediate or spring, depending on whether the plant is prostrate, intermediate or erect respectively in the early stages before true stems appear. Stems are erect, simple, usually glabrous with 5 to 7 nodes and usually hollow internodes (Peterson, 1965; Agric. Canada, 1977).

The leaf has two main parts, the sheath and the blade. The sheath is curved, forming a tube around the stem. The leaf blade is narrow, flat and acuminate, about 20 - 37cm long and 1.2cm wide, with prominent parallel veins (Peterson, 1965; Purseglove, 1975).

The inflorescence is a terminal, cylindrical, compound distichous spike, between 5 and 10cm long with tough non-shattering axis (the rachis). Spikelets are sessile, arranged alternately in two rows with one terminal spikelet (Fig.2). A spikelet contains a variable number of florets. A fertile floret in turn consists of the lemma and palea enclosing a caryopsis. The lemma, which is boat-shaped usually has an awned apex. The palea is thin and membranous. The floret has 3 stamens with bilobed anthers, an obovate ovary having 2 short styles with a feathery terminal stigma. The florets are largely self-pollinated. Each spikelet contains about 2 oval grains with a central groove on the ventral

FIG. 2 WHEAT


THE SPIKE
Front and Side view
g
h
f
Flower
f outer glume
g lemma
h palea

surface, usually with a terminal tuft of hairs (the brush). There are about 14 - 20 spikelets per spike. 1,000 - seed weight is about 50g (Peterson, 1965; Agric. Canada, 1977).

4. Culture and Adaptation

Wheat is primarily a temperate crop but has been grown under a variety of conditions. It is poorly adapted to warm or moist conditions but a combination of high temperature and high atmospheric humidity usually leads to complete failure or unthriftiness((Peterson, 1965; Martin and Leonard, 1970; Purseglove, 1975). The temperature range for optimum growth is $15^{o} - 25^{o}C$ (Friend *et al.*, 1963; Macdowall, 1973; Spiertz, 1974).

It is best adapted to fertile, medium-textured to heavy-textured soils that are well drained. Silt and clay loams give the highest yields. It requires fair quantities of nitrogen (N), phosphorus (P), and potassium (K) together with a balanced supply of the secondary and trace elements. It is known that yield and tillering rate increase with increasing levels of N. Beyond 100kg N per hectare, however, tiller survival and lodging (especially in tall cultivars) become problems (Jessop and Pethica, 1969).

The seed may be broadcast or drilled at a depth just enough to give it adequate moisture (about 2.5 - 5.0cm deep) in rows 20 - 25cm apart. Seed rate varies from 50 - 200kg per hectare depending on cultivar and environmental conditions (Purseglove, 1975). Rainfall between 250mm and 1,800mm per annum can support the crop but supplementary irrigation could increase yield considerably (Martin and Leonard, 1970).

Several pests and diseases attack the wheat crop. According to Purseglove (1975) and Mensah (1979), the most destructive diseases include stem and leaf rusts (Puccinia graminis and P. triticina) and head blight (Fusarium spp.). Other diseases include bunt (Tilletia spp.), smut (Ulstilago tritici) and mildew (Sclerospora macrospora). The latter group has not been reported in Ghana (Mensah, 1979).

Time to maturity ranges from 95 - 150 days. The world average yield as given by the Food and Agricultural Organisation (F.A.O.) in 1967 was 1,420kg/ha but yields vary considerably around the world. Purseglove (1975) reported yield averages of 900kg/ha and 1,000kg/ha for Asia and Kenya respectively. The average yield in Canada has been given as about 1,500kg/ha while yields of 4,000kg/ha are not uncommon in Denmark and the Netherlands. A world record yield of 8,808kg/ha obtained in England in 1952 is yet to be exceeded (Agric. Canada, 1977).

5. Effects of Light on Wheat

As compared with other photo-sensitive temperate species, wheat is known to have some resilience as regards limitations by photoperiod. Most wheat cultivars are quantitative long-day crops, tending to flower sooner the longer the daylength, without a minimum daylength under which flowering will not be initiated at all (Swaminathan, 1973;

Evans et al, 1975). For example, Pugsley (1965) observed that certain cultivars that usually come into ear in 52 days under long days (13.5 - 14.5 hrs.) took 94 - 132 days to reach that stage under short days (10.5 - 11.5 hrs.). Martin and Leonard (1970) also cite the examples of Kenya (12 hrs. average daylength) and Alaska (20 hrs. daylength) where wheat is known to grow to maturity, to show the wide range of daylengths under which the crop can be cultivated. Obligate long-day cultivars exist, however, which will not initiate flowering when daylength falls below the critical limit of 12 hours. Rawson (1971) has reported, however, that extremely long days tend to reduce spikelet number, grain number and therefore yield. He noted an inverse relationship between daylength and spikelet number in wheat.

In Ghana, daylength varies between 11.8 and 12.4 hours throughout the year, and this precludes the cultivation of photo-sensitive cultivars here. As reported by Aryeetey (1970/71), a few of the cultivars included in a wheat trial in Ghana did not initiate flowering at all. This may be attributed to their photo-sensitivity.

The effects of light intensity on wheat performance have also been studied. At atmospheric carbon dioxide levels, most wheat cultivars are known to be saturated for light needs at about 8.0 - 9.8 cal. cm^{-2} h^{-1} (Swaminathan, 1973; Evans et al, 1975). Observations made by other experimenters corroborate this low light saturation point in wheat. Absolute and relative growth rates in most cultivars of wheat have been found to increase with increasing light intensities up to 8.0 - 9.8 cal cm^{-2} h^{-1} (about a third that of full sunlight) when the leaves get light-saturated (Friend et al.,1962;1963; Swaminathan, 1973; Spiertz, 1974). Tillering also is favoured and rate of apparent photosynthesis increased under increasing light intensities up to about 8.0 cal. cm^{-2} h^{-1} (Friend,1966).

There is some evidence that high light intensities, as pertains in the tropics on sunny days may prove deleterious to wheat performance. Lockhart (1961) noted a destruction of gibberellins in maize at full sunlight, limiting cell expansion and stem elongation. If this observation will hold for wheat, then the crop will be reduced in size in areas of high light intensities, resulting in low productivity.

Light seems to have little effect on pollen though long days of about 14 - 16 hours are known to reduce viability slightly (Welsh and Klatt, 1971).

6. Effects of Temperature (Heat) on Wheat

Optimal temperatures for germination and vegetative growth of wheat lie between 20^{o} and 25^{o} C. The minimum and maximum temperatures are 3^{o}- 6^{o} C and 30^{o} C respevtively. From these cardinal temperatures it is apparent that wheat grows under cooler conditions in general than it will in Ghana (in the Lowland Tropics) where temperatures are usually higher. Consequently, exposing the crop to the relatively high temperatures that pertain here could severely inhibit growth.

Generally as temperatures extend either below or above the extreme limits for growth of any crop, thermal injury increases until ultimately the crop dies as a result of metabolic failure (Langridge and McWilliam, 1967). According to Langridge and McWilliam even at non-lethal temperatures, metabolism could get disrupted as toxic products accumulate with a depletion of essential metabolites in the crop.

As is apparent from the following observations, temperatures above the optimal range for wheat growth, tend to affect a number of physiological processes which often lead to poor performance of the crop.

(i) Pre-emergence and Vegetative Phases

Poor emergence and seedling mortality have been observed in wheat where temperatures have exceeded a maximum day temperature of 30° C (Swaminathan, 1973). Chlorophyll formation in wheat also appears to have a critical temperature-dependence. At 34°C Friend *et al.* (1962) observed that an increase of about 0.5°C resulted in yellowing, stunted growth and death.

Even though high temperatures have been reported to stimulate tillering and leaf formation (Martin and Leonard, 1970), maximal photosynthetic area is reportedly reduced with increasing temperatures as a result of narrower, thinner leaves and shortened stems (Friend, 1966). Ishag and Taha (1974) have also attributed the incidence of high tiller mortality they observed, to the high temperatures (33°C by day; 18°C by night) that prevailed during their experiment.

The importance of crown depth soil temperature has also been demonstrated by Smika (1974). He found that crown depth temperatures accounted for 83 - 98% of the variation in the yield components, number of ears/plant and spikelets/head in spring wheat. With winter cultivars he found a positively curvilinear correlation between crown depth temperatures and the components, tillers/plant, heads/plant, spikelets/head and weight/head. Noggle and Frietz (1976) have reported results in maize consistent with the above. They observed maize plants to increase in size as root temperature was increased from 12^{o} -26^{o}C and then beyond that resulted in a decrease in plant size. It is possible that the higher temperatures disrupted certain physiological processes within the crown of the plants, since tiller number and head size are known to originate from the crown (Smika, 1974). The optimum root zone temperature for wheat is 20^{o}C (Nielson, 1974).

(ii) Reproductive Phase and Maturity

Owen (1971) and Macdowall (1973) have observed that after ear emergence in wheat, high temperatures resulted in complete failure of the grain crop whereas these same temperatures (35^{o} and 30^{o}C day temperatures; 18^{o} and 13^{o}C night temperatures) imposed only up to floral initiation had no effect on 1,000-grain weight. This may be due to the observation that grain size is determined mainly by conditions after anthesis (Evans *et al*., 1975).

According to Evans et al., high temperatures after anthesis may even cause sterility.

Temperature has pronounced effects on the duration of both the vegetative and reproductive phases in wheat. Nuttonson (1955) found that the duration of the vegetative phase in wheat was strongly and linearly related to the mean daily effective growing temperature. According to van Dobben (1962) high temperatures shorten the period of growth in wheat without giving sufficient compensation by faster growth and as a result the plants remain smaller than they would in cool climate. This affects photosynthetic capacity and hence yield. Duration of grain filling is also known to continue for a longer period at temperatures lower than 25°C while higher ones tend to speed up the course of development, resulting in lower grain yields (Wattal, 1965; Spiertz, 1974). There is grain shrivelling also when hot weather with maximum day temperatures beyond 30°C sets in before grain filling is completed (Swaminathan, 1973). Asana and Williams (1965) observed a 16% reduction in grain size due to shrivelling when temperatures were increased from 25° to 31°C. For successful grain production in wheat therefore, the critical day temperature after anthesis lies between 32° and 35°C (Owen, 1971).

Pollen viability and net assimilation rate (N.A.R.) are known to be reduced under high temperatures (Friend, 1969; Owen, 1971; Welsh and Klatt, 1971). Friend (1969) noted a 47% reduction in N.A.R. when temperatures were increased from the optimal range of 15°- 20°C to 25°- 30°C.

Both dark and photo-respiration rates are increased with increasing temperatures (Stoy, 1965; Jollife and Tregunna, 1968).

The effects of environmental conditions on protein storage in wheat have not been extensively examined. High temperatures however seem to reduce atarch storage more than that of protein, resulting in small kernels rich in gluten (Campbell and Read, 1968; Martin and Leonard, 1970). The critical temperature above which baking quality of high-protein wheats is lowered is about 32°C (Martin and Leonard, 1970).

(iii) Thermoperiodicity

A plant that shows increased growth or performance under alternating temperature conditions is said to be thermoperiodic (Friend and Helson, 1976). Several plant species are known to respond favourably to alternating diurnal temperatures (usually high day and low night temperatures) but the generality of the phenomenon has been questioned since some species seem to be insensitive to it. Generally, optimal temperatures for photo-processes are higher than those for nycto-processes (Friend and Helson, 1976), and nycto-processes are particularly important since the growth of plants is known to occur predominantly at night (Langridge and Mc-William , 1967).

According to Friend (1966) and Friend and Helson (1976) there is some superiority of constant temperatures over alternating day and night temperatures for growth and dry matter accumulation in wheat, peanuts and sugarcane. They found the optimum temperature for both day and night as 25°C for wheat. Peters *et al.*(1971), however,have remarked that high night temperatures reduce grain yields remarkably. Working under induced night temperatures of 8.9°,15.3° and 26.5°C they reported that the highest night temperature produced a grain yield almost half that of the lowest temperature. They attributed the reduced yield to earlier senescence and maturity, and hence a shortened grain filling period which they associated with the high night temperatures.

(iv) Thermal Requirements

It has been observed that certain plants require a definite amount of heat to bring them through a complete cycle from planting to maturity (Nuttonson, 1955; Langridge and McWilliam, 1967). A number of synonymous units have been used but that of "heat units" will be employed in this thesis.

To determine the summation of heat units for a crop, a base temperature, often the minimum temperature below which very little physiological activity occurs in the crop, is used (Peterson, 1965). The difference between the mean daily temperature and the base temperature gives the number of heat units for the day. The sum of these daily quantities throughout the growth period gives the total heat requirement of the crop. Sometimes the mean monthly or mean weekly temperatures are used instead of the mean daily ones in determining thermal efficiency (heat requirement). The base temperature often used for wheat is 4°C (Peterson, 1965).

From observations made in wheat studies, the number of total heat units required by each growth phase is nearly constant (Nuttonson, 1955; Venkataraman and Kazi, 1972). The higher the mean day temperature the shorter the duration of growth.

The indiscriminate use of the heat unit system, however, is not agreeable to some researchers. According to Went (1953) the procedure proposed a linear relationship between mean day temperatures and growth, which did not exist, especially for thermoperiodic plants like potato and chilli pepper in which predominantly night temperatures control tuber and fruit formation. He however submitted that it could be used over a limited range of temperatures for crops that are less sensitive to thermoperiodicity like wheat and peas. Brown (1960) also contended that the system gave too much weight to temperatures over 27°C. He suggested that such temperatures may even be detrimental to the crops. Under this system, mean day temperatures rather than the daily temperature ranges are given prominence whereas the ranges are often of more significance (Chang, 1968).

In spite of its lack of theoretical soundness, however, the heat unit system may be helpful in corroborating the reports cited above on the effect of high temperatures in shortening the developmental period of growth in crops. Using meteorological data , the heat unit approach has been useful in the determination and forecast of sowing dates, to ensure the best duration of active growth phases for wheat in India (Venkataraman and Kazi, 1972). In Canada, a similar type system is used to define where and when different cultivars of maize should be grown (Brown, 1976).

7. Effects of Moisture and Humidity

Water requirements of wheat increase when the head appears and grain begins to form. It has been estimated that about 85 - 120 tonnes of water are required to produce 100kg of wheat (Agric. Canada, 1977). Under moisture stress, there are modifications in certain vegetative and reproductive structures in wheat. Leaf area is reduced (Dubetz and Bole, 1973) and fewer tillers are produced. Tillers that are produced have higher sterility levels and reduced seed set (Peterson, 1965; Agric. Canada, 1977). Excess moisture can also be detrimental (Gangopadyaya and Sarker, 1967). Although it is known that above average moisture during germination and shortly thereafter is beneficial to wheat, a similar condition during tillering was found to be detrimental (Gangopadyaya aand Sarker, 1967). This may be due to the low consumptive use of water by the crop at the tillering stage. The daily consumptive use of water for wheat is known to be low up to the boot stage, increasing thereafter up to grain formation.There is a decrease in water use of the crop during the grain maturing period (Patil, 1976).

Most plants grow well under high atmospheric humidities except when saturated air persists for weeks and completely stops transpiration. Many plants are capable of directly absorbing moisture from unsaturated air of high humidity (Chang, 1968). According to Baker (1965) photosynthetic rate increases with humidity in cotton, especially under high light intensities. Peters (1960) noted a significantly higher rate of water use in corn at 40% R.H. than at 95% R.H. in the early stages of growth. With time, however, the difference in water use as controlled by relative humidity became almost negligible due to the faster rate of growth at 95% R.H.. Under a mist environment automatically activated at ear temperatures above 25^{0}C, Laing and Fischer (1976) found a slower grain growth during grain filling which they attributed to lowered ear temperature due to misting. According to them misting had no effect on final grain size and grain yield.

High relative humidity *per se* therefore appears to have little or no adverse effects on wheat performance. Wheat is known, however, to perform poorly in environments with a combination of high relative humidity and hot weather (Peterson, 1965; Purseglove, 1975). From work done by Al'tergot and Mordkovich (1976) high relative humidity and hot air affected the water status of rudimentary ears thus disrupting ear structure and decreasing grain yields, even under conditions of normal water supply.

Another reason for the poor performance of wheat in humid regions is the conducive environment created for fungal diseases. Leaf diseases are especially encouraged. A combination of warm and moist weather is known also to favour rust development. Martin and Leonard (1970) have reported stem or black rust (*Puccinia graminis tritici*), leaf rust (*P. recondita*) and stripe rust (*P. glumarum*) as the most common rusts so encouraged in wheat.

III

MATERIALS AND METHODS

1. Kpong: The Project Environment

(i) Location

Kpong lies at the interception of latitude 06° 07′N and longitude 00° 04′E, in the Eastern region of Ghana (West Africa). It forms part of a much larger low-lying land mass, the Accra Plains, which is bounded in the west by the Akwapim Range and Weija hills, in the north and east by the right bank of the lower Volta River, and in the south by the sea. The gross area of this climatic zone, the Accra Plains, is 335,540 hectares (Aryeetey, 1978). The area utilised for this research is about 8 metres above sea level.

(ii) Climate and Soil

Kpong experiences two rainy seasons as is characteristic of the Accra Plains, with a mean annual rainfall of about 1270mm (Fig. 3). Air temperatures are highest during the main dry season (November to February) and the lowest in the short season of July - August. Soil temperatures are relatively higher than air temperatures but with a similar trend.

Atmospheric humidity is generally higher in the mornings than in the afternoons with averages of 77% and 64% respectively, for 0900 hours and 1500 hours GMT. Daylength is reasonably constant, varying from about 11.8 hours in December to 12.4 hours in June. The climate here is characterised by constant heat, daylength and humidity, the modest reduction in temperatures at night affording little relief to the daytime heat.

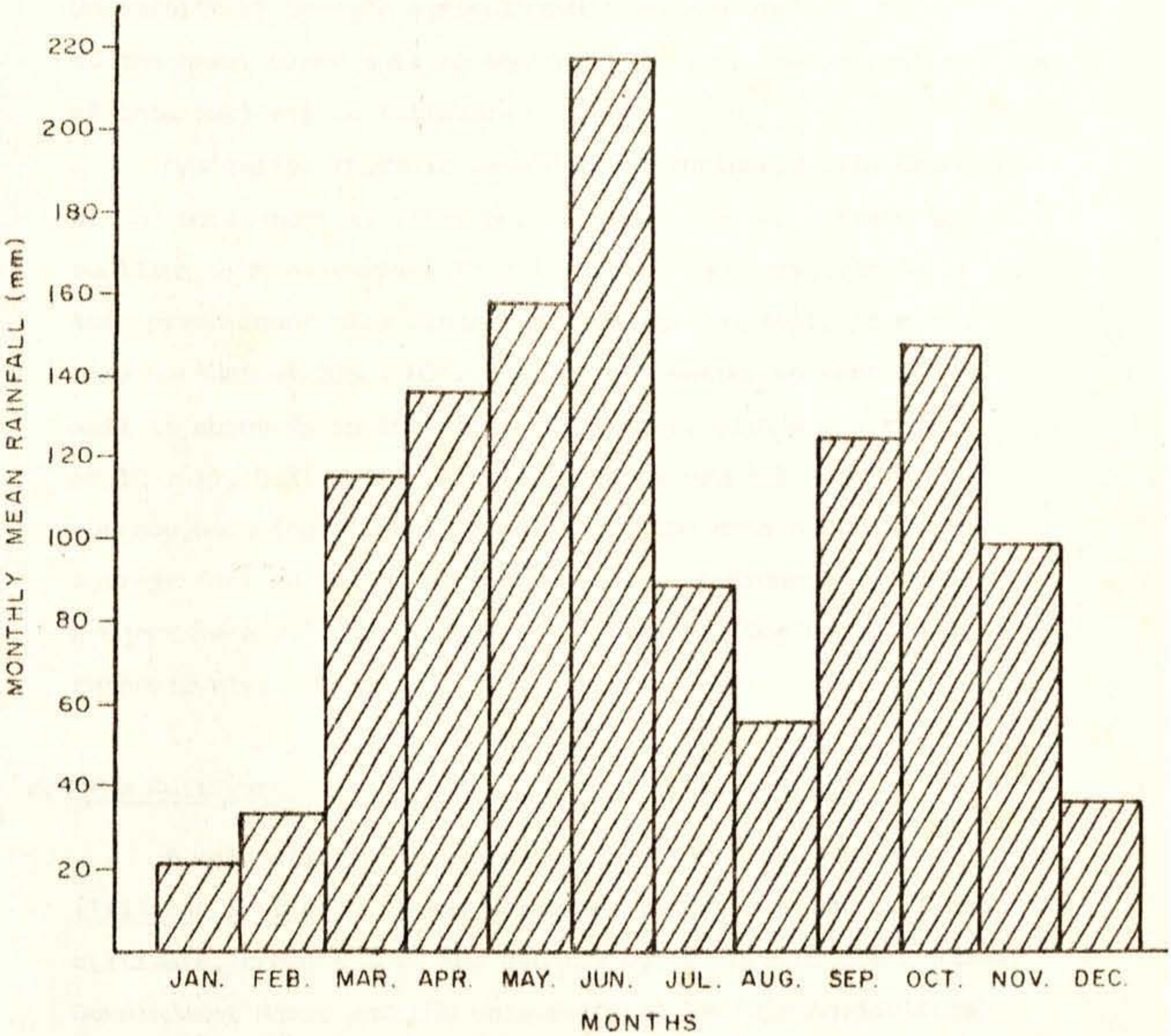


FIG. 3 ANNUAL RAINFALL PATTERN FOR KPONG (Accra Plains)
(Average for 21 years)

The main soil type at the site of this project (the University of Ghana's Agricultural Research Station, Kpong) is the heavy black soil of the Akuse series. The characteristics of this soil are as follows:-

Physically, there is considerable shrinkage with cracking of the soil when it dries up. As it becomes wet, there is swelling with expansion. This is because Montmorillonite is the predominant clay mineral present in the soil. It has a clay content of 30% - 60%. The organic matter content of the soil is about 4% in the first six inches, with a C/N ratio of 12 : 17. Soil pH is slightly acid or neutral near the surface, becoming slightly alkaline in the deep sub-soil. The average soil pH values at the immediate environment of the project were 7.3 and 7.5 for the depths 0 - 5cm and 15 - 30cm respectively.

2. The Cultivars

A collection of sixteen cultivars of common wheat (*Triticum aestivum* L.) was assembled for this project. These cultivars, brought into the country by the Grains and Legumes Development Board and the University of Ghana's Agricultural Research Station (Kpong) to be tested for their adaptation to Ghanaian conditions, were from the following countries: Canada (the Canada gene source centre), Mexico (the International Maize and Wheat Improvement Centre -- CIMMYT), Pakistan, India and Egypt. All available information on the cultivars used in this project are as follows:

Accession Number	Cultivar	Origin
1.	BLUE SILVER	Pakistan
2.	LYALLPUR-73	Pakistan
3.	PUNJAB-OP-78	India
4.	7438 - AE	Canada
5.	7438 - AB	Canada
6.	7423 - K4	Canada
7.	7438 - D	Canada
8.	7438 - X	Canada
9.	7438 - AY	Canada
10.	GIZA 157	Egypt
11.	GIZA 158	Egypt
12.	S.A. 42	Pakistan
13.	S,A. 75	Pakistan
14.	SANDAL	**
15.	MEXIPAK	Mexico
16.	CHENAB 70	Pakistan

** Origin not known.

3. Planting and Harvesting

The cultivars were planted in a four-replicate, randomised complete block layout at the following planting dates: 19th December 1978, 18th January, 23rd May, 20th June, 18th July, 20th August, 25th September, 22nd October, 23rd November and 18th December 1979.

The plots, each of two rows (0.2m apart and 1.0m long) were sown 0.4m apart with pathways 1.0m wide between blocks of plots. Seed was drilled at a rate of 6g per plot (150kg/ha). Where germination was very poor, additional seed was sown after emergence to afford a fair stand.

The fertilizer mixture 15-15-15 (N-P-K) was applied as split dressings to give a total of 100kg N per hectare. The first dressing was done 10 days after germination and the second 14 days later. The plots were kept as weed-free as possible by either hand picking or hoeing. Supplementary irrigation was done by means of watering cans when necessary. "Gammalin 20" was sprayed every fortnight as a measure against insect pests, at 1% concentration. Poisoned baits were placed around the experimental area to prevent rodent attacks.

Harvesting was done by cutting off spikes with a sickle as they matured in the plots. The harvested spikes were then stored in brown paper envelopes and kept in an air-conditioned room until each plot was completely harvested. Threshing was done by hand.

The first two plantings were used as a preliminary study. This was because only accessions 1 - 9 were available by then.

There were no plantings in February, March and April because not enough seeds were available. Furthermore, it is known that when the stages from grain-filling to maturity coincide with wet weather, wheat yields are reduced and grain quality is also lowered due to pests and diseases which are encouraged by such an environmental condition. Planting in February - April would have exposed the crop to the major rainy season (March-April to mid-July) while in the critical stages mentioned above.

4. Data Collected

The following measurements were taken.

A. From Germination to Anthesis

(i) Days to germination:	The number of days from planting to seedling emergence in each plot.
(ii) Initial stand:	A visual appraisal of seedling stand, done at 10 days after planting.
(iii) Days to anthesis:	The number of days from seedling emergence until 50% of the plants in a plot had flowered.
(iv) Number of leaves per plant at anthesis:	The mean number of leaves per plant from a random sample of 5 plants from each plot.

B. After Anthesis to Maturity

(i) Tillering rate per plant:	The mean number of tillers per plant counted from a random sample of 5 plants from each plot during grain-filling (including non-productive tillers).
(ii) Fertile tillering percentage:	The proportion of seed-bearing tillers as against the total number of tillers counted within a length of 0.4m in each row of a plot, during grain-filling.
(iii) Days to maturity:	The number of days from seedling emergence until the majority of spikes had brown-matured in each plot.
(iv) Plant height:	The mean of measurements taken on a random sample of 10 plants from each plot; measuring from the base of the plant to the tip of the spike of the main axis (at the base of the awns), at maturity.
(v) Lodging score:	Done on the visual rating of 1 (when all plants were erect) through 10 (when all plants had fallen on the ground) at harvest.

C. Harvesting and After

(i) Number of spikelets per spike:	The mean number of spikelets per spike on 5 spikes picked at random from each plot.
(ii) Number of seeds per spikelet:	Five spikes were randomly picked from each plot. From each of these, 3 spikelets were removed (from the distal, mid and proximal sections of a spike). The spikelets (15 in all) were then threshed together and the mean number of seeds per spikelet determined.
(iii) Grain yield per plot:	Weight of seed (13% moisture) threshed from each plot.
(iv) Grain yield per plant:	Calculated from the weight of seed threshed from each plot, divided by the number of plants per plot at harvest.
(v) Total dry weight per plant:	Five whole plants were randomly selected from each plot and uprooted at maturity. Seed from these plants were threshed out and weighed and the straw oven-dried for about 48 hours at 110°C and weighed. Total dry weight per plant was calculated as the mean of the bulked weights of oven-dried plants and threshed seed

from the 5 plants.

(vi) 1,000- grain weight: A sample of 200 seeds were picked from total threshed seed for each plot and weighed. 1,000-grain weight was calculated by multiplying this weight by the factor 5.

(vii) Number of spikelets per plant: This was calculated as the product of measurements B(i), B(ii) and C(i) for each plot.

(viii) Seed quality score: Done on the visual rating of 1 (Plump and disease-free looking seed) through 10 (badly shrivelled and diseased looking seed) for each plot.

The moisture content of harvested seeds from each plot was determined by means of the Dickey-John Moisture Tester (Dickey-John Corp.; Auburn, Illinois, U.S.A.).

D. Climatic Data

Meteorological data which included rainfall, air and soil temperatures and daily sunshine duration were collected from a meteorological station situated about 100m from the area of the project. The mean monthly maximum, minimum and day temperatures as well as relative humidity values were determined from this data for the entire period of the project.

Daily heat unit accumulations for each cultivar were also computed for each planting date experiment as described in Section II 6(iv). See Appendix IV. Average daily solar radiation figures for a cloudless sky on latitude 06° 00'N are also presented in Appendix III as quoted from Riley (1979).

5. Statistical Treatment of Data

The results of the whole project, which was laid out under split plot in time design, were analysed as described by Steel and Torrie (1960).

A statistical technique which was developed by Finlay and Wilkinson (1963) was adopted and used to compare the performance of the wheat cultivars sown at the different planting dates. For each cultivar, a linear regression of individual yield on the planting date mean (all cultivars combined) was computed and from the regression coefficients "b" obtained, conclusions were drawn regarding the adaptability of the cultivar. In the calculation of means and regression coefficients referred to above, the basic yields were measured on a logarithmic scale in order to induce a high degree of linearity and a reasonable degree of homogeneity of experimental error (Finlay and Wilkinson, 1963).

In this thesis use is made also of another stability parameter, the deviation from regression mean square (S_d^2) as a measure of stability (Eberhart and Russell, 1966). These parameters may be defined with the following model.

$$Y_{ij} = \bar{X}_i \quad b_i I_j \quad d_{ij}$$

where Y_{ij} is the cultivar mean of the i^{th} cultivar at the j^{th} environment, $\bar{X}_i$ is the mean of the i^{th} cultivar over all environments, b_i is the regression coefficient that measures the response of the i^{th} cultivar to varying enironments . (e.g. climatic conditions due to planting dates), d_{ij} is the deviation from regression of the i^{th} cultivar at the j^{th} environment (planting date) and I_j is the environmental index obtained as the mean of all cultivars at the j^{th} environment minus the grand mean (Eberhart and Russell, 1966).

Three important stability parameters were therefore used in this study, namely: (i) The regression coefficient (b),

(ii) the cultivar mean yield over all environments ($\bar{X}_i$) and

(iii) the deviation from regression mean square (S_d^2), which is the sum of the squared deviations, d_{ij}, in the model.

A "b" value approximating to 1.0 indicated average stability. When this was associated with a high mean yield, $\bar{X}_i$, the cultivar had general adaptability. When associated with a low mean yield, the cultivar was poorly adapted to all environments. When b values increasingly deviated above or below 1.0, they described cultivars with below and above average stability respectively (Finlay and Wilkinson, 1963).

The cultivar mean yield over all planting dates provided a comparative measure of performance of individual cultivars.

The smaller the value of S_d^2 , the more stable the cultivar in that its yield in each environment (or for each planting date) was closely similar to the value predicted by its regression line (Abington, 1972).

By means of this technique, the cultivars used in this project were compared as regards stability. The planting dates were also compared by means of the planting date mean values of all cultivars at each planting (a component of I_j in the model).

By means of the meteorological data, reasons were adduced to explain the relative performance of the cultivars in the different seasons (planting dates).

IV

RESULTS AND DISCUSSION

1. General Observations

The average number of days to seedling emergence was 4 - 5 days with a generally fair crop stand. Incidence of disease was not severe. An unidentified disease whose symptom was the "white-head" was observed, however, in all plantings and in all cultivars. The symptom may be due to the common root rot disease (*Helminthosporium* and *Fusarium* spp.) which is known to lead to this premature blight symptom. Sporadic incidence of stem and leaf rusts (*Puccinia graminis* and *P. triticina* respectively) were also observed.

The most important insect pests noticed on the crop were the grasshopper (*Zonocerus variegatus*) and the Ladybird beetle (*Hippodamia convergens*). These were controlled by spraying 1% "Gammalin 20" insecticide.

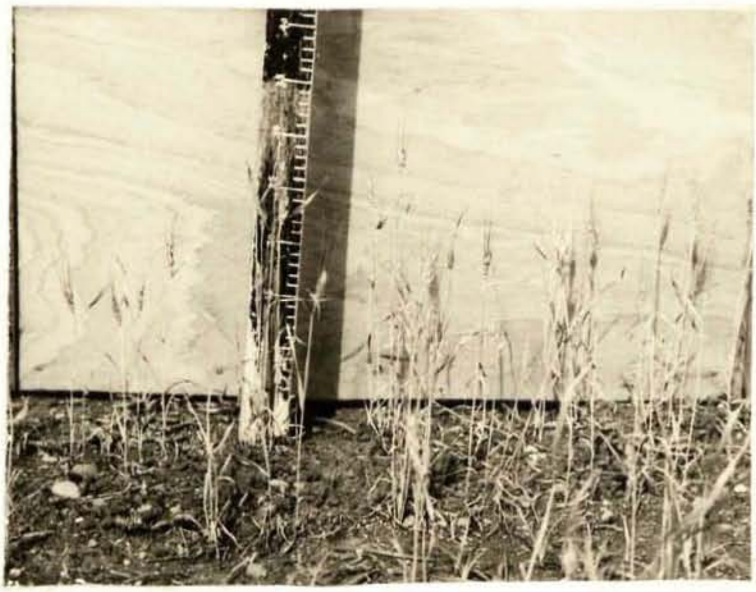
The importance of time of planting to the performance of wheat was underscored by the highly significant effect of planting date on all the characters studied (Appendices V - VII). In the Lowland Tropics where climatic conditions are generally not ideal for the growing of wheat, time of planting appears to be an important factor to consider. See Plates 1(a) and 1(b).

The results presented and discussed below are mainly from data collected from the May to December 1979 monthly plantings. Indication is given where data from the preliminary trial is included.

PLATE 1

Pictures taken of cultivar 16 in (a) the June, and (b) September plantings.

(a) June planting.



(b) September planting.

The mean monthly temperatures, relative humidity, mean daily percentage sunshine and monthly rainfall during the project are shown in Figs. 4(a) and 4(b).

2. Effect of Planting Date

Trends in planting date mean values followed a characteristic bimodal pattern for most of the characters studied (Figs. 5(i) - (xiii) and Table 1). From this general trend, three planting seasons can be demarcated, namely:

(a) The first planting season: Comprising the May, June and July 1979 plantings. The growth of the crop in these plantings lasted from late May to early October 1979.

(b) The second planting season: Comprising the August, September and October 1979 plantings. In these plantings the growth of the crop lasted from late August 1979 to early January 1980.

(c) The third planting season: Comprising the November and December 1979 plantings. Growth of the crop in this season lasted from late November 1979 to early March 1980.

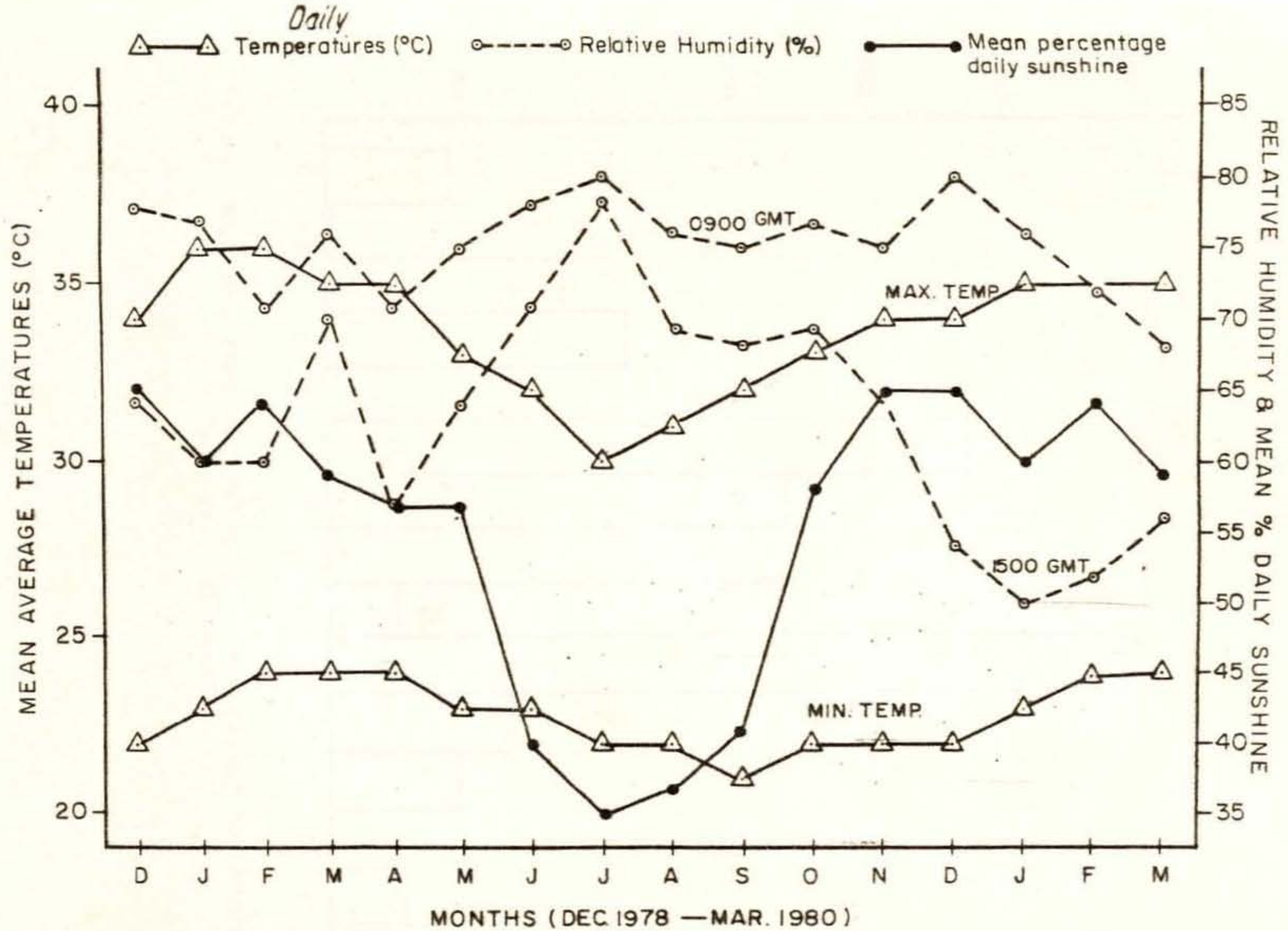


FIG. 4a MONTHLY MEAN TEMPERATURE, RELATIVE HUMIDITY AND DAILY PERCENTAGE SUNSHINE PATTERN DURING PROJECT

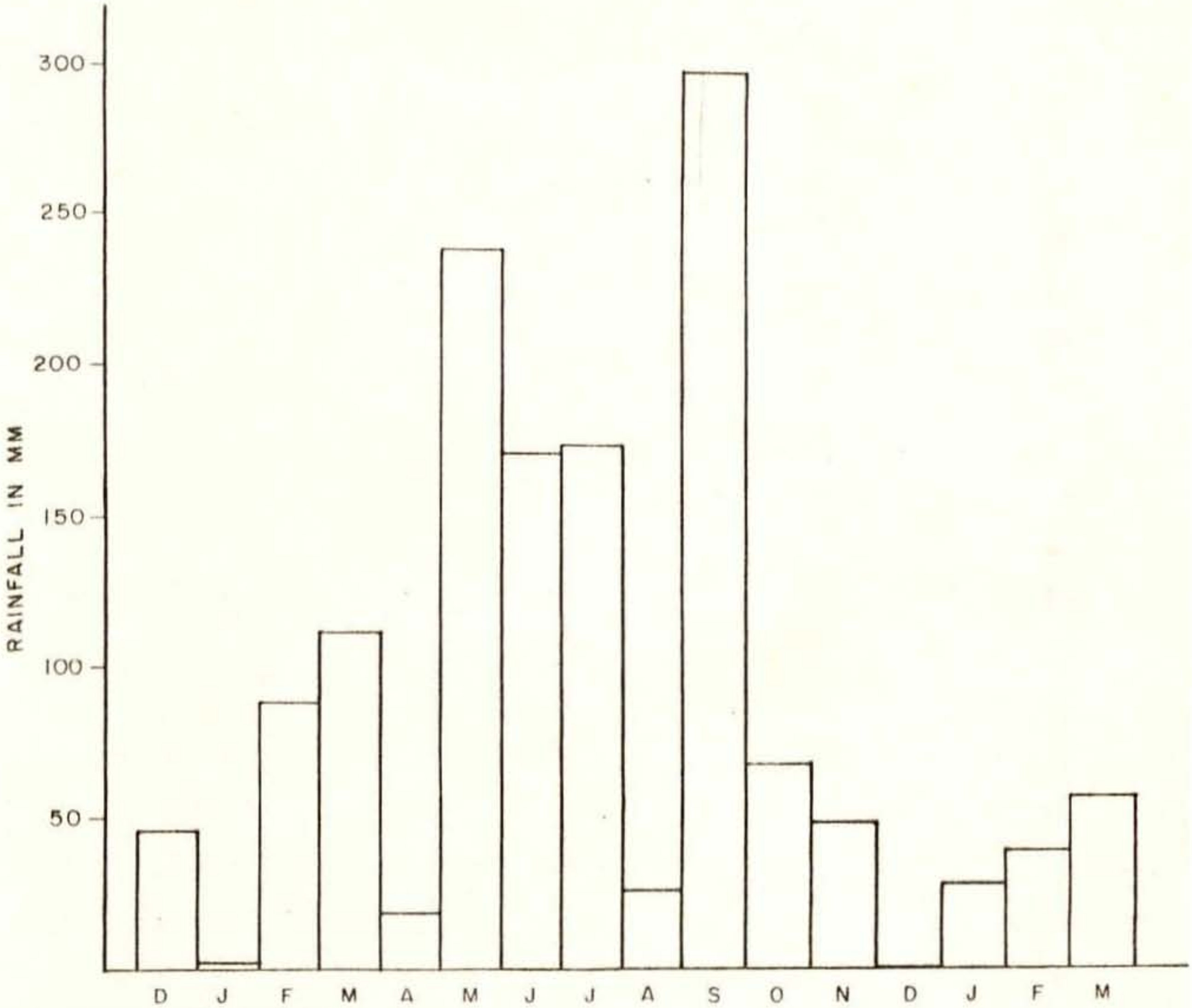


FIG. 4b MONTHLY RAINFALL PATTERN DURING PERIOD OF PROJECT
(Dec 1978 — Mar 1980)

TABLE 1: EFFECTS OF PLANTING DATE ON ALL CHARACTERS S

PLANTING DA

CHARACTER	23RD MAY 1979	20TH JUNE 1979	18TH JULY'79	10TH AUGUST
Total dry matter wt. per plant (g)	3.89 B	4.68 A	2.31 D	1.32 F
Tillering rate	5. 5 A	5. 7 A	4.8 B	3.4 C
Fertile tellering percentage (%)	67 CD	73 AB	63 DE	64 DE
Plant height (cm)	54.5 B	59.9 A	37.5 E	37.9 E
No. of leaves/ plant at anthesis	26 B	26 B	24 C	20 D
No of days to anthesis	54 A	49 C	46 D	45 D
No. of days to maturity	79 A	70 B	64 D	61
Lodging Score	2.00 A	1.50 B	1.50 B	-
Seed quality score	3.3 AB	3.4 A	3.3 AB	3.3 AB
Grain yield/ plant (g)	0.95 B	1.30 A	0.35 DE	0.10 F
No. of seeds per spikelet	1.1 C	1.2 BC	1.3 AB	0.9 D
No of spikelets per plant	74.9 B	84.0 A	56.3 C	39.3 D
Thousand-grain weight (g)	29.5 B	32.5 A	23.0 C	20.5 D
Calculated mean grain yield/plot (kg/ha).	903 B	1,435 A	245 CD	135 D

FOOT NOTE: Horizontal means with the same alphabet indicate non significance

3 -

STUDIED ON 16 CULTIVARS OF WHEAT AT KPONG

DATE

ST'79	25TH SEPT,'79	22ND OCT.'79	23RD NOV.'79	18TH DEC.79	STANDARD ERROR
F	0.44 G	1.71 E	2.25 D	3.31 C	0.1008
C	2. 4 D	3. 2 C	3. 4 C	4. 4 B	0.1426
E	67 CD	61 E	76 A	71 BC	1.4327
E	24.6 F	38.5 E	48.7 D	50.8 C	0.5238
D	7 F	17 E	23 C	28 A	0.6662
D	52 B	48 C	43 E	48 C	0.4388
	70 B	66 C	61 E	67 C	0.4538
	1.25 C	1.0 D	1.5 B	1.0 D	0.0545
AB	3.2 B	3.3 AB	2.9 C	2.8 C	0.0515
F	0.05 F	0.25 E	0.40 D	0.70 C	0.0395
D	0.8 D	1.4 A	1.3 AB	1.2 BC	0.0395
D	17.5 E	37.3 D	41.8 D	70.1 B	2.2860
D	19.5 D	25.0 C	29.5 B	29.0 B	0.9782
D	38 D	368 C	455 C	823 B	39.3492

ce at the 5% level, under Duncan's Multiple Range Test.

The observed trends may be attributed to the variation in climatic factors during the project. See Figs. 4a and 4b.

2A. Effect of Planting Date on Yield Related Characters

(i) Total dry weight per plant: Mean total dry weight per plant for the different planting dates is illustrated in Fig. 5(i). The trend showed that the first planting season was significantly the most favourable for the accumulation of dry matter, the peak being for the June planting. This was followed by the third season with a peak in the December planting. The second season appeared the least favourable, particularly the September planting. The comparatively low temperatures (mean daily maximum of $30^o - 32^oC$) and the high rainfall that characterised the first planting season (Figs. 4a & 4b) may account for the significantly higher dry matter accumulation for the plantings in this season as compared to those of the other two seasons.

Generally, high temperatures are known to shorten the vegetative phase in wheat without sufficient compensation by faster growth (van Dobben, 1962; Andrews, 1969) and hence a reduced potential for dry matter accumulation.

- 40 -

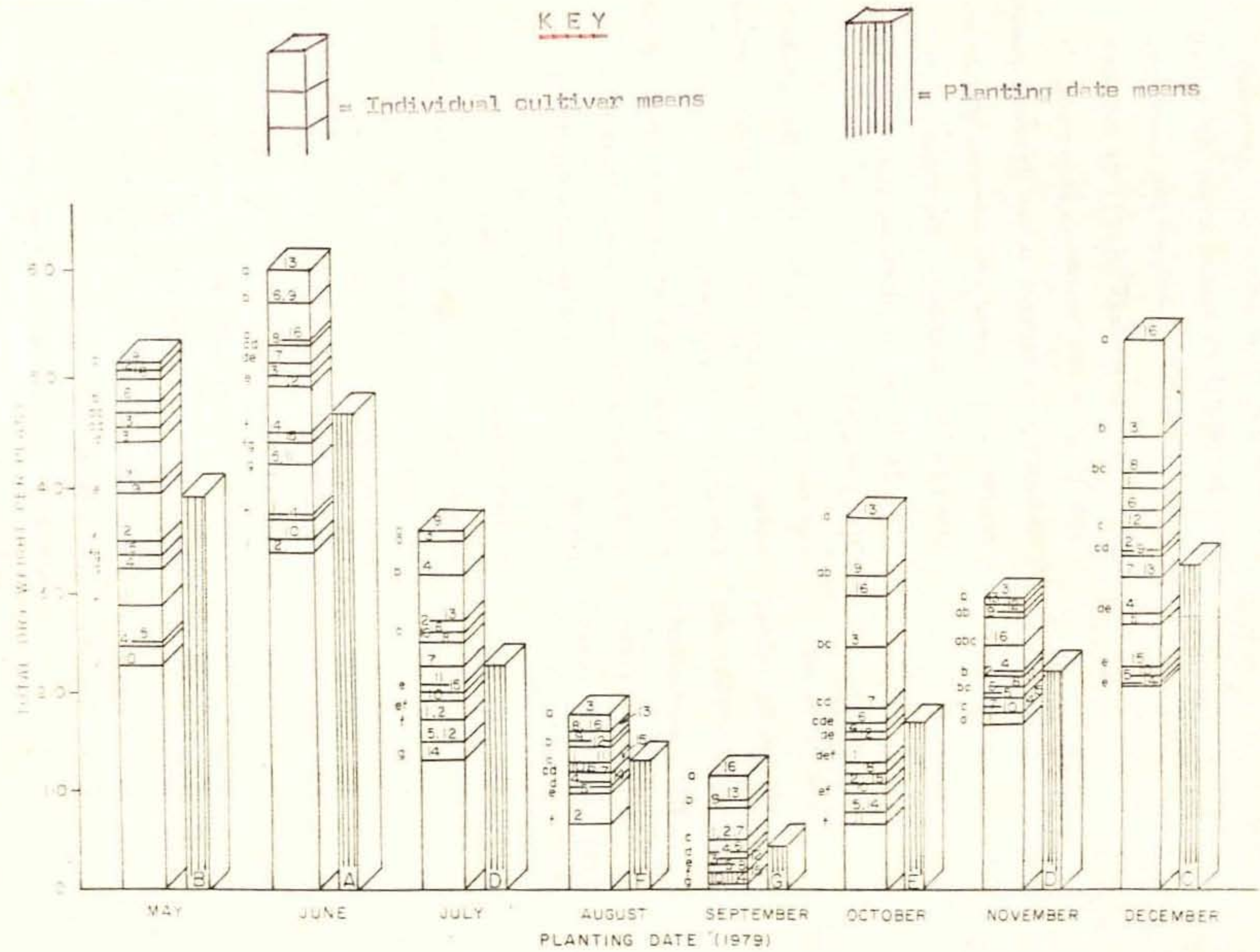


FIG 5 (1) EFFECT OF PLANTING DATE ON TOTAL DRY WEIGHT PER PLANT

Relative growth rate (R.G.R.) which determines dry matter accumulation is also known to reduce with increasing temperatures in wheat (Friend et al., 1962). This may be due to increased respiration rate and its concomitant sharp reduction in net assimilation rate (N.A.R.) known to be associated with high temperatures (Friend, 1966;.Jollife and Tregunna, 1969).

One could surmise that the above observations were the cause of the trend in dry matter accumulation.

(ii) Tillering rate, fertile tillering percentage, plant height and number of leaves per plant at anthesis:

The effect of planting date on these characters followed trends similar to that for total dry weight per plant. From the following observations, the same reasons given for the trend in dry weight per plant may hold here also (See Figs. 5(ii) - 5(v)).

It has been observed that when maximum air temperatures exceeded 30°C, tillering in wheat was reduced due to a shortened vegetative phase (Swaminathan, 1973). From the observed trend for tillering rate (Fig.5(ii)) it appears that there is a progressive reduction in tillering as temperature increased beyond the 30°C threshold. This may

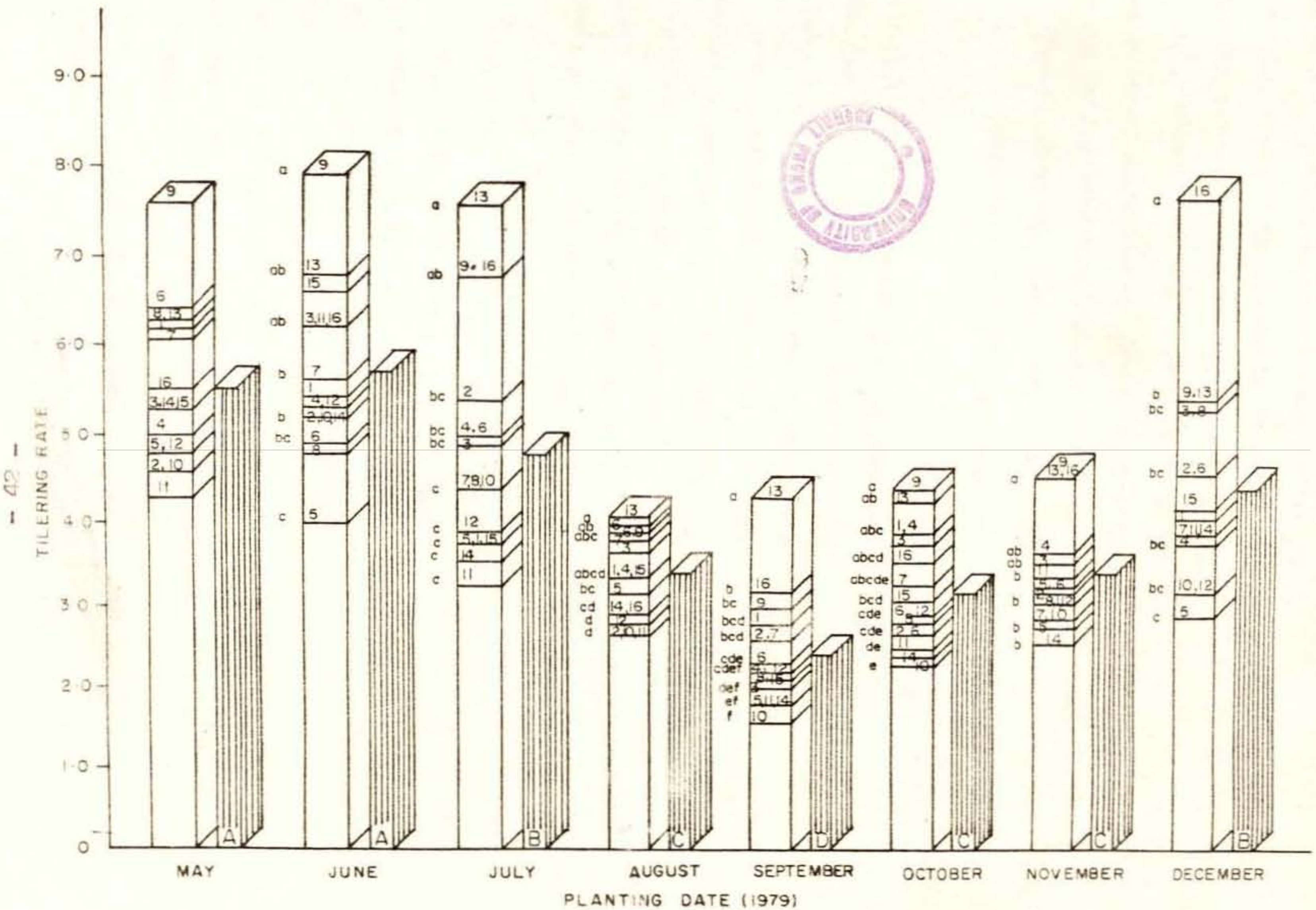


FIG5(II) EFFECT OF PLANTING DATE ON TILLERING RATE account for the poorer tillering observed in the second and third planting seasons as compared to that of the first season. Tiller mortality is also known to be associated with high temperatures (Ishag and Taha, 1974).

Although increases in both daylength and total radiation (a function of daily percentage sunshine) tend to increase total leaf number, temperatures above 25°C increasingly reduce it (Friend, 1966). This may account for the significantly higher values observed in number of leaves per plant at anthesis in the first season as compared with the other two seasons. The significantly higher number of leaves per plant observed in the third season over that in the second season, may also be as a result of the relatively shorter duration of daily sunshine in the third season.

The relatively smaller plants observed in the second and third planting seasons may also be accounted for by the relatively higher temperatures recorded in these seasons as compared to those of the first season. Although high light intensities are known to stimulate stem growth (Friend, 1966), high temperatures above 25°C tend to

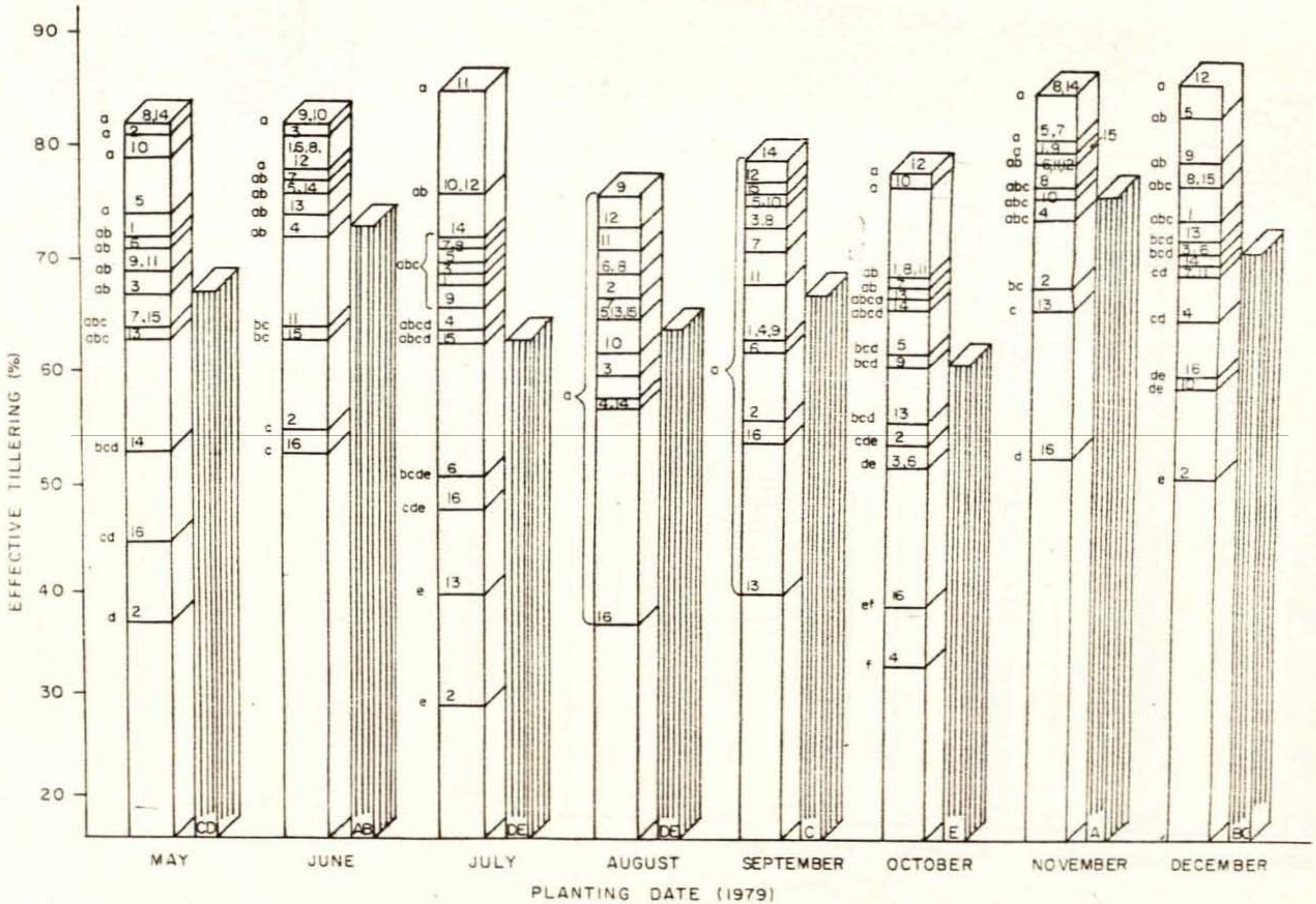


FIG 5 (III) EFFECT OF PLANTING DATE ON FERTILE TILLERING PERCENTAGE

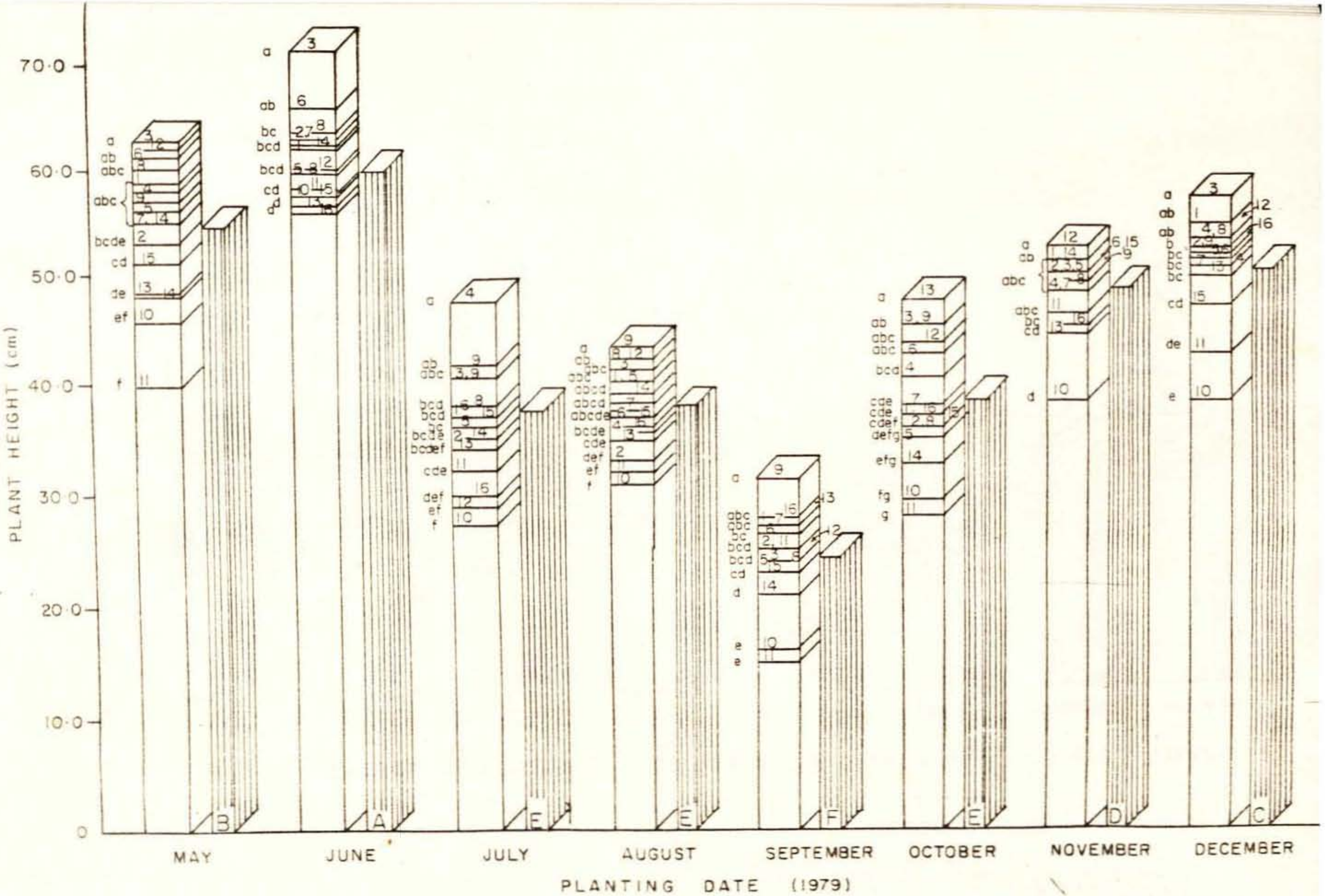


FIG. 5 (IV) EFFECT OF PLANTING DATE ON PLANT HEIHGT

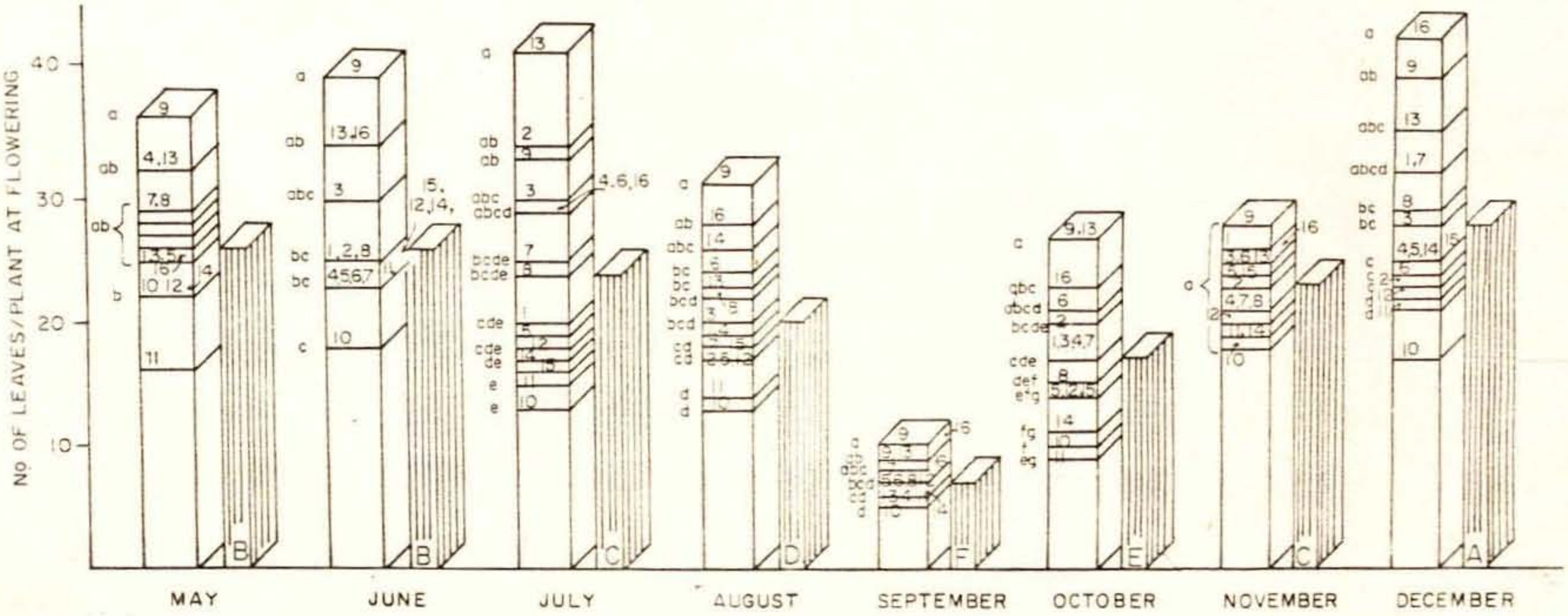


FIG. 5 (V) EFFECT OF PLANTING DATE ON No OF LEAVES PER PLANT AT FLOWERING

shorten the period of vegetative growth, resulting in smaller plants (van Dobben, 1962).

(iii) Number of days to anthesis and maturity: The phases, emergence to anthesis and emergence to maturity were longest during the first planting season, followed by the second and then the third seasons (Figs. 5(vi) and 5(vii)). In consonance with the heat unit concept which suggests an inverse relationship between temperature and the characters, days to anthesis and days to maturity, temperatures were observed to generally increase from the first planting season through the second to the third season (Fig.4a). It follows from the concept that the higher the mean day temperature, the shorter the duration of growth and vice versa (Nuttonson, 1955; Venkataraman and Kazi, 1972). Van Dobben (1962) has also reported that there was a shortened duration of growth in wheat due to high temperatures. Hence, although high temperatures often accelerate physiological processes, they tend to shorten the developmental period of growth in wheat.

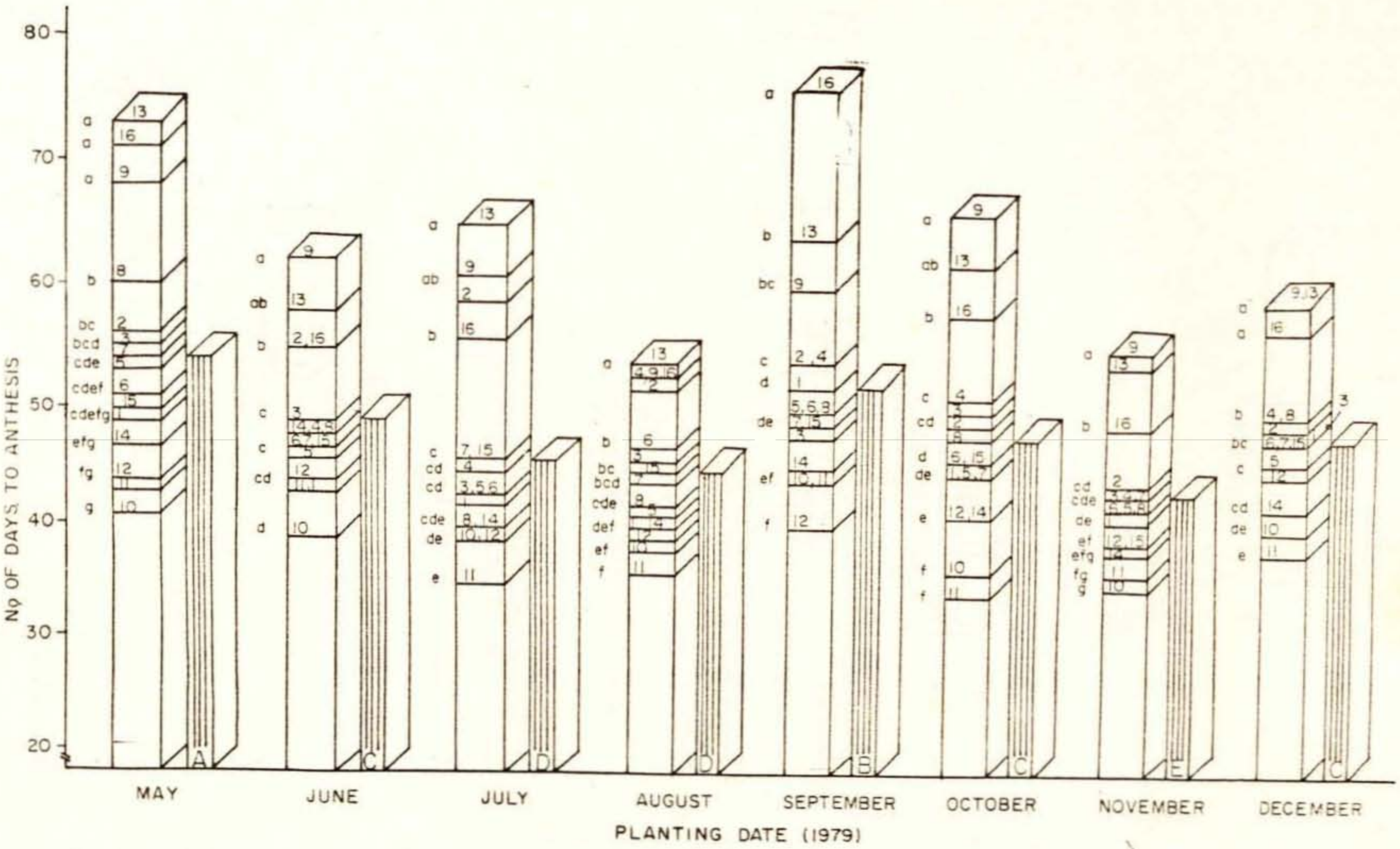


FIG. 5(VI) EFFECT OF PLANTING DATE ON No OF DAYS TO ANTHESIS

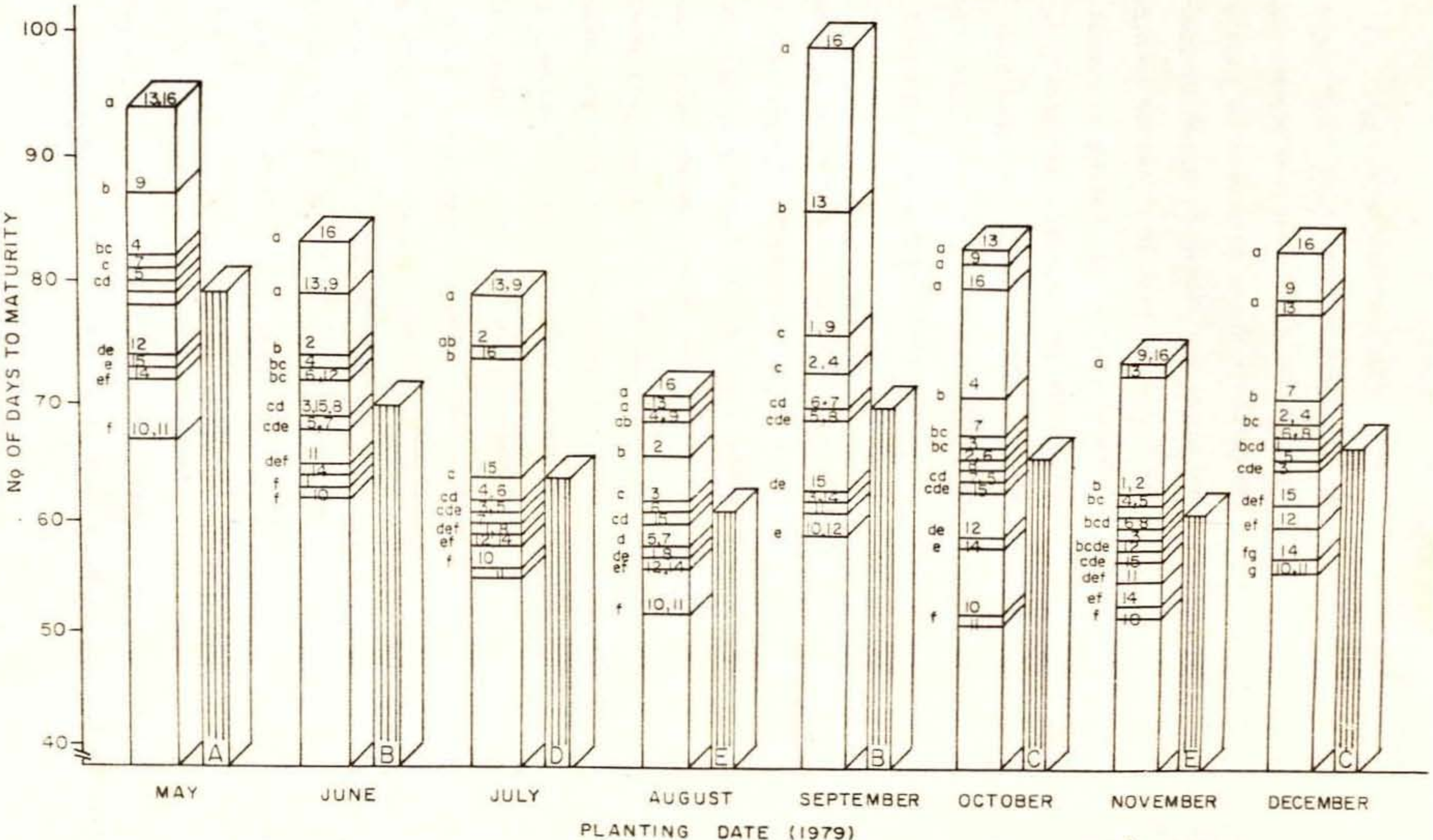
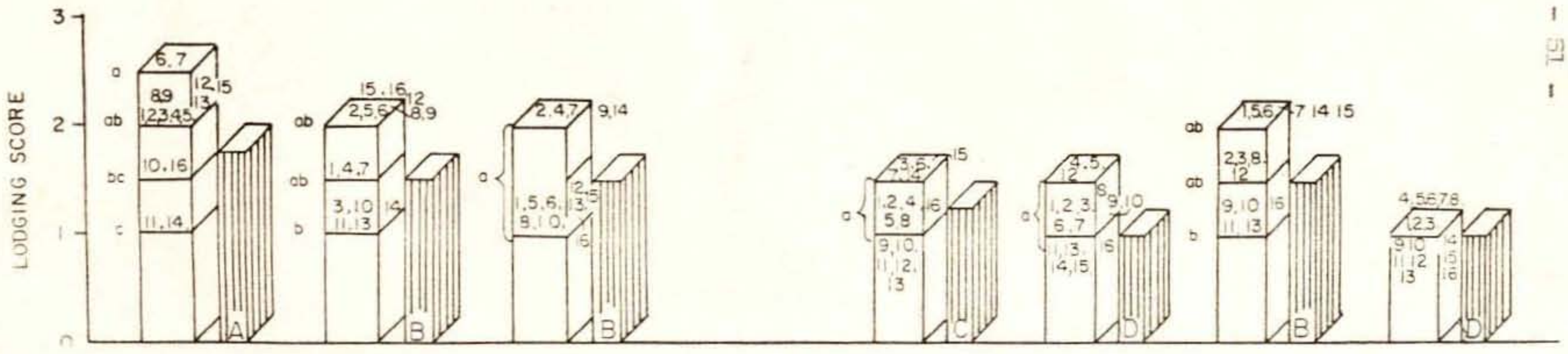


FIG. 5 (VII) EFFECT OF PLANTING DATE ON No DAYS TO MATURITY

(iv) Lodging and seed quality scores: Planting date mean values for lodging score (Fig. 5(viii)) indicate highest lodging during the first season, followed by the third and then the second seasons. The heavy rains(and the winds that usually accompany them) during the first planting season may be responsible for the high lodging observed in that season (Fig.4b). The rains toward the end of the third planting season may be responsible for the higher lodging observed during that season as compared to that of the second season. There was little rainfall towards the end of the second season which was advantageous to the crop. According to Neenan and Spencer-Smith (1975) wind and rain are among the main causes of lodging in wheat.

Seed quality(as defined in this project) was best during the third season (Fig. 5(ix)). This may be attributed to the relatively low relative humidity (R.H.) recorded during this period as compared to the generally high R.H. values recorded in the first and second planting seasons. High humidity is known to encourage fungal activity on the glumes and seeds, leading to discoloured seeds (Peterson, 1965; Mensah, 1979) as was observed.

FIG. 5(VIII) EFFECT OF PLANTING DATE ON LODGING IN WHEAT



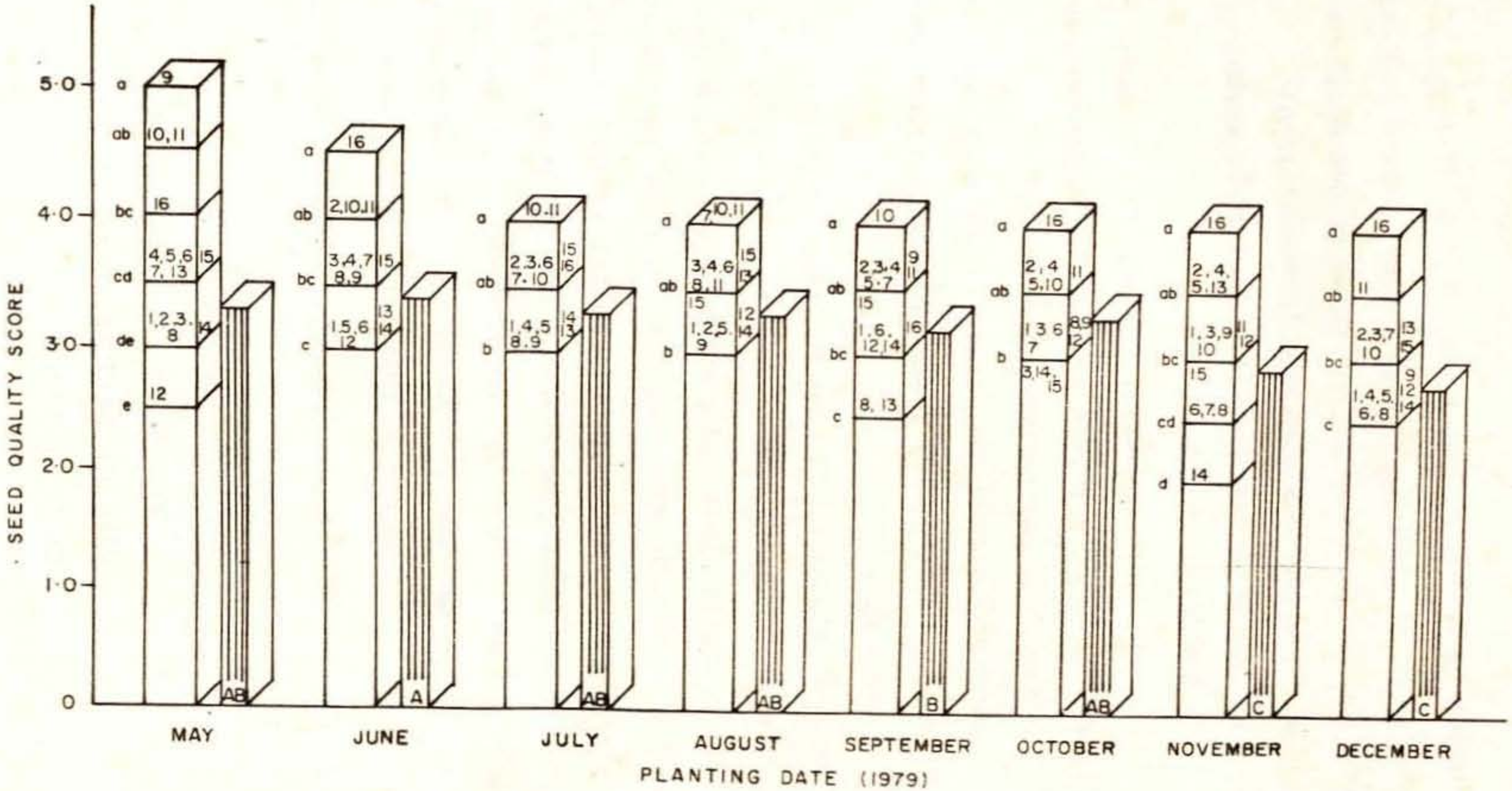


FIG. 5 (IX) EFFECT OF PLANTING DATE ON SEED QUALITY (VISUAL)

Grain shrivelling is also known to accompany high temperatures at grain filling, especially as temperatures increase above 30°C (Asana and Williams, 1965).

2B. Effect of Planting Date on Grain Yield and its Components

The first planting season (particularly the June planting) was significantly the most favourable for grain production (Fig. 5(x)). This was followed by the third season while the second season proved the least favourable. A similar trend was observed in the expression of the yield components, namely: number of seeds per spikelet, number of spikelets per plant and unit grain weight (Figs. 5(xi)-(xiii)). This trend may be attributed to the variation in climatic conditions that prevailed during the project.

Three key stages recognised in grain formation and crop yield in cereals are:

(i) The stage of floral initiation and inflorescence development when the potential spikelet and floret numbers are determined (Ryle, 1966),

(ii) the stage of anthesis and fertilisation when the degree to which this potential is realised, is fixed (number of seeds per spikelet) and

(iii) the stage of grain filling when grain weight is supposed to progressively increase (Slatyer, 1970).

Optimum temperatures for the three stages mentioned above are known to be between 18° and 25°C with maximum and minimum temperatures given as 10° and 32°C (Evans *et al.*, 1975) respectively.

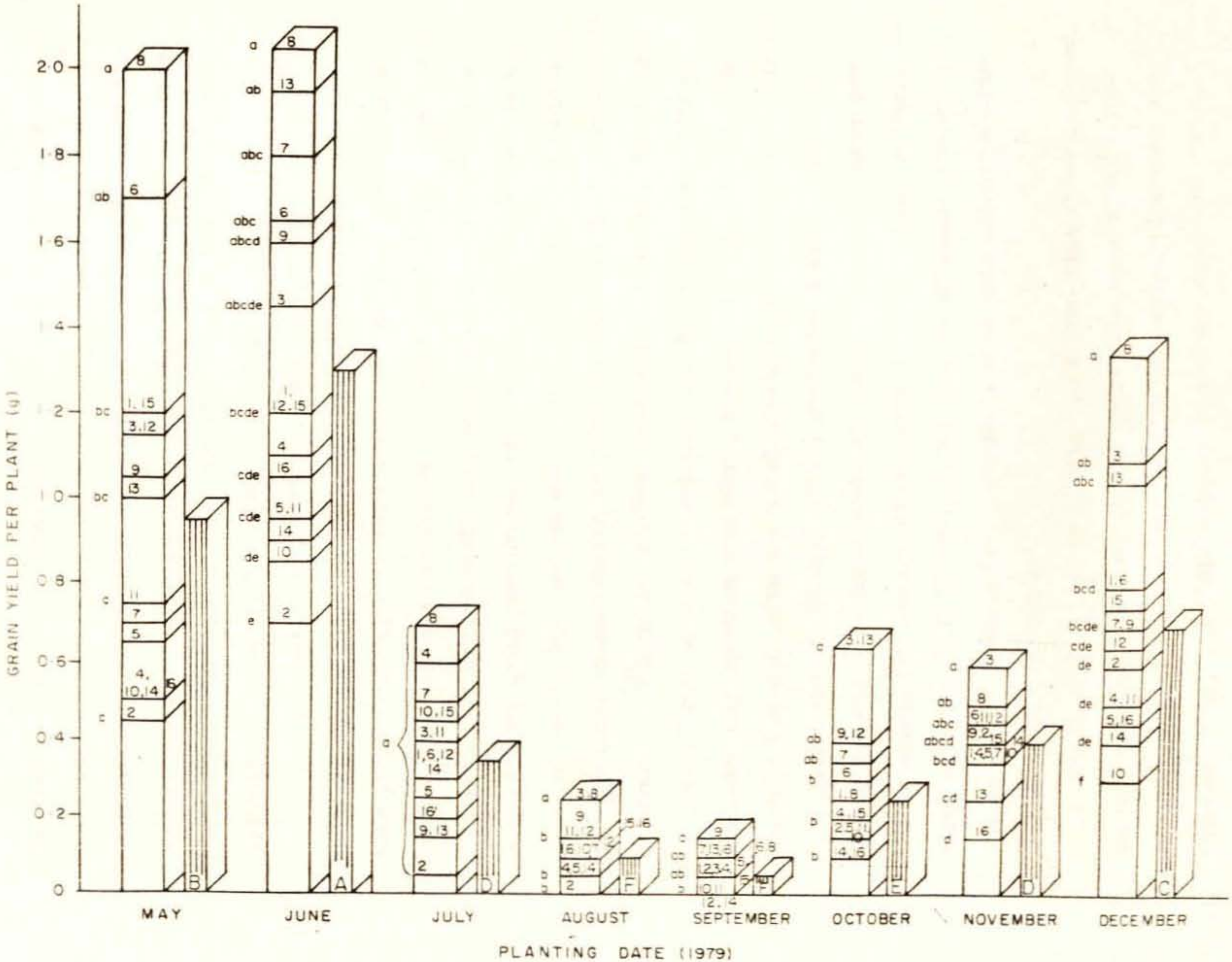


FIG. 5 (X) EFFECT OF PLANTING DATE ON GRAIN YIELD PER PLANT

Temperatures below and above these minimum and maximum limits are debilitating and may result in complete failure or even death of the crop. At high temperatures as were generally observed during the project, the crop is known to undergo stress, particularly during the first two stages, when the crop is most susceptible (Owen, 1971; Macdowall, 1973).

The combination of relatively low temperatures and good rainfall during the first planting season may account for the best yield production in this season. At the high temperatures (relative to optimum conditions for wheat growth) that prevailed during the project, adequate available moisture could well be a requisite for good performance of wheat. It is known that as a means of protection against heat (thermal injury) wheat plants undergo rapid transpiration in order to maintain leaf temperatures of about 1 - 2^{o}C below ambient temperatures (Henckel, 1964) thereby losing large volumes of moisture to the atmosphere. Without adequate soil moisture therefore, the crop is subjected to stress which is known to affect several physiological processes in wheat.

According to Slatyer (1972) prolonged stress induces a marked reduction in total spikelet number and grain number per ear in wheat. Net photosynthetic rate is also reduced at temperatures of about 30^{o}C (Friend, 1966) thereby affecting the accumulation of grain dry matter especially when this coincides with the grain filling period.

Since grain yield production in a crop like wheat is based, to an appreciable extent, on its vegetative structure (photosynthetic size) attained by the time of anthesis (Bunting and Drennan, 1966) the yield related characters discussed above,

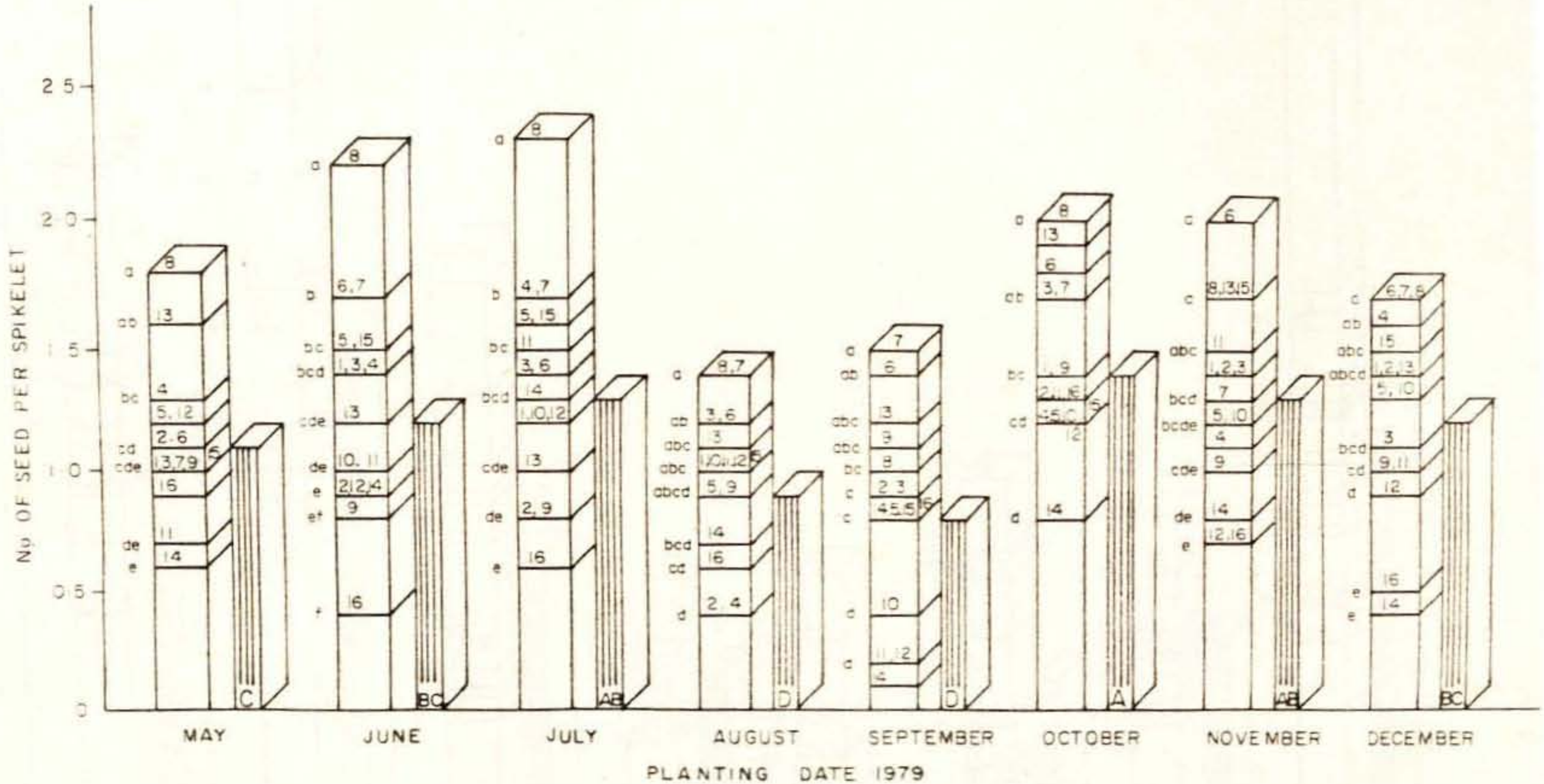


FIG. 5 (XI) EFFECT OF PLANTING DATE ON No SEEDS PER SPIKELET

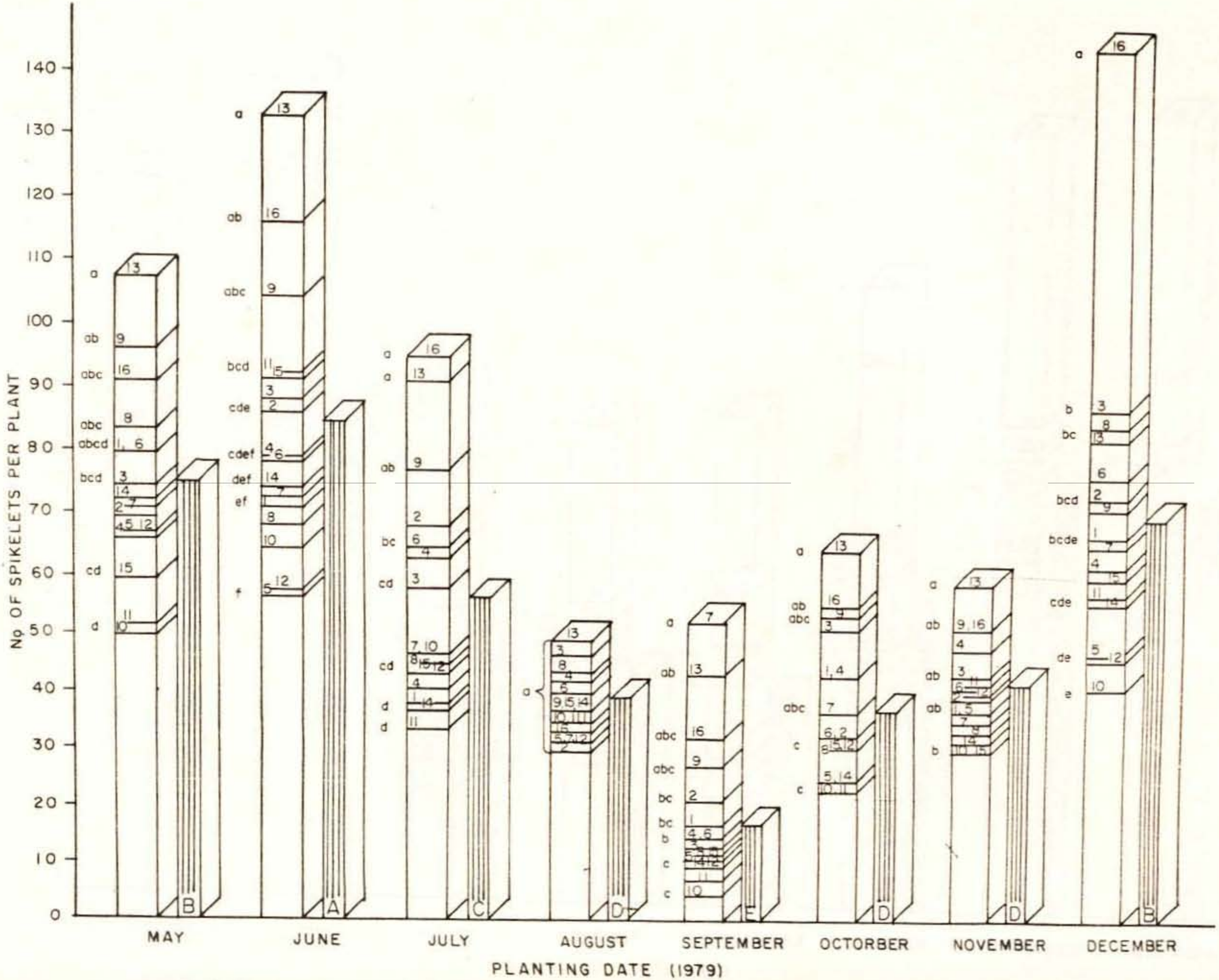


FIG. 5 (XII) EFFECT OF PLANTING DATE ON No OF SPIKELETS PER PLANT

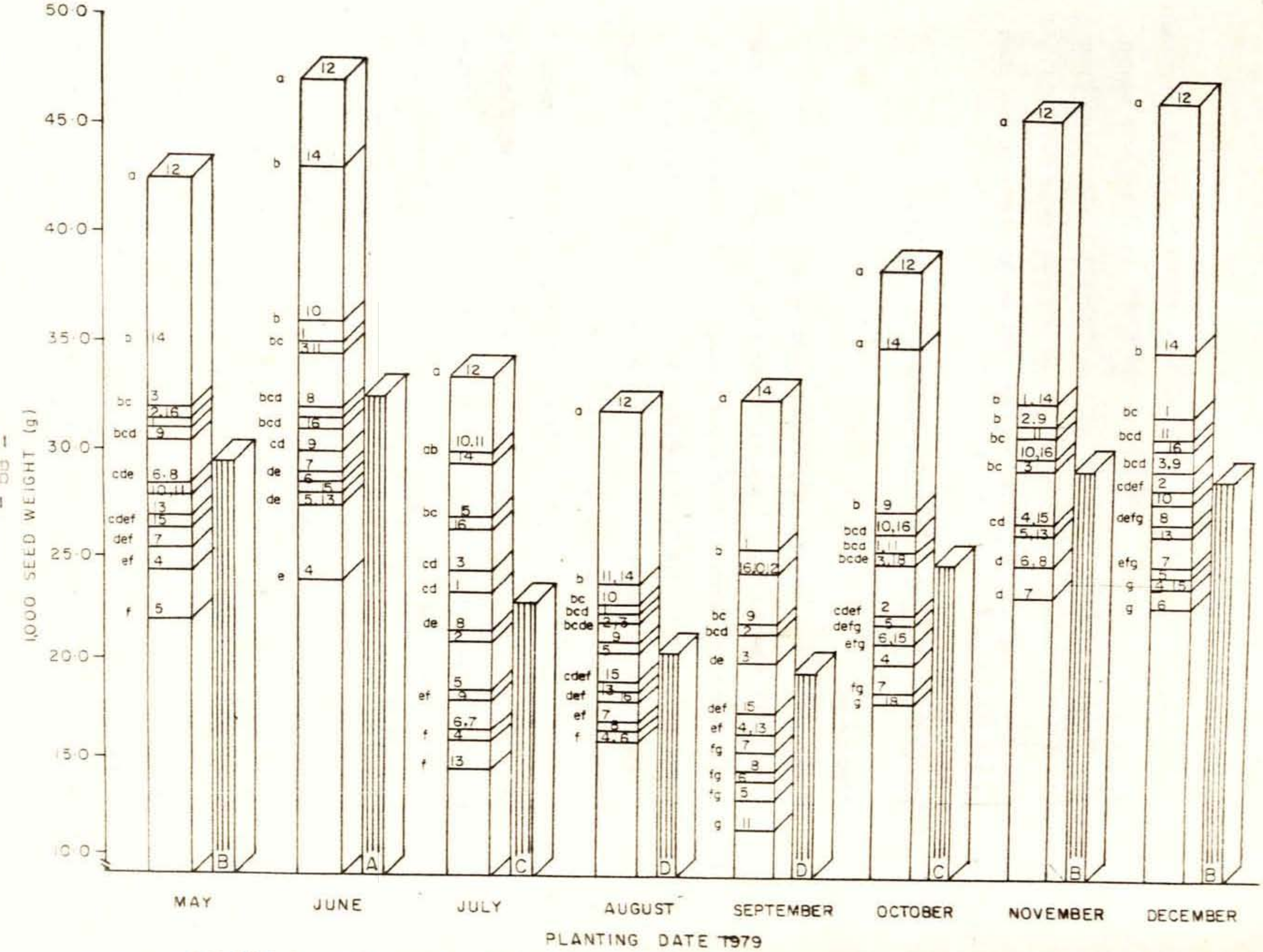


FIG.5(XIII) EFFECT OF PLANTING DATE ON 1,000 SEED WEIGHT are likely to have had important direct effects on grain dry matter accumulation and hence may partially account for the trend observed in grain production.

It is apparent from the general trend in planting date mean values for all the characters studied that the first planting season (the June planting in particular) was the most favourable to the performance of wheat. This was followed by the third season. The second season (particularly the September planting) was the least favourable. As has been explained above, the combination of relatively cool temperatures and good rainfall during the first planting season may likely be responsible for the observed trend. It is possible that inadequate watering during the second season may have led to the comparatively better performance of the crop in the third season even though temperatures were slightly higher in the latter season than in the former. One could surmise here that at high temperatures such as prevailed during the project, moisture may be a factor more limiting to wheat performance than small increases in temperature.

3. The Cultivars: Their Performance and Adaptability

A. Performance

(i) Growth duration and potential yield capacity: Although the growth duration of the crop appeared to be reduced, most probably due to the high temperatures that prevailed during the project, the cultivars could be classified as follows, on the basis of their overall mean growth duration values:

(a) Early maturing cultivars with up to 60 days duration. These were cultivars (accessions) 10, 11 and 14.

(b) Medium duration cultivars with 61 - 75 days duration, namely; accessions 1, 2, 3, 4, 5, 6, 7, 8, 12 and 15.

(c) Late maturing cultivars with 76 - 85 days duration, comprising accessions **9, 13 and 16.**

Linear correlations were carried out among the characters studied (using the overall cultivar mean values) and the coefficients are presented in Table 2. From these coefficients, growth duration (number of days to maturity was observed to have a strong association with certain characters, namely; number of spikelets/ plant, tillering rate, number of days to anthesis, total dry weight / plant and fertile tillering percentage. Except for the last character which showed a negative but strong correlation with growth duration, the others gave positive correlations. These relationships point to the importance of a long growing period in enhancing the potential yield capacity in a crop like wheat (van Dobben, 1962 Rawson, 1970; Yoshida, 1972). The strong and negative correlation between growth duration and fertile tillering percentage may be attributed to the high temperatures that generally prevailed during the project. High temperatures are known to be associated with low pollen viability and tiller mortality (Khan *et al.*, 1971;Ishag and Taha, 1974).

TABLE 2: LINEAR CORRELATIONS AMONG THE CHARACTERS STUDIE[D]

CHARACTER		CORRELATION COEFFICIENTS				
		X_2	X_3	X_4	X_5	X_6
Grain yield/ plant	X_1	0.795**	0.211	-0.239	0.594**	0.491
Seeds/spikelet	X_2		0.016	-0.676**	0.226	0.330
No of Spikelets/ plant	X_3			-0.234	0.824**	0.268
1000-Seed weight (g)	X_4				-0.081	-0.254
Total dry weight/plant	X_5					0.532**
Plant height (m)	X_6					
Tillering rate	X_7					
No of days to anthesis	X_8					
No of days to maturity	X_9					
Fertile tillering percentage (%)	X_{10}					
No of leaves/ plant at anthesis	X_{11}					
Lodging Score	X_{12}					
Seed quality Score	X_{13}					

FOOT NOTE: * and ** Indicate significance at 5% and 1% levels respectively

)IED (USING OVERALL CULTIVAR MEAN VALUES

X_7	X_8	X_9	X_{10}.	X_{11}	X_{12}	X_{13}
0.343	0.112	0.038	0.310	0.299	0.205	-0.388
0.110	0.010	-0.001	0.194	0.116	0.429	-0.210
0.933**	0.921**	0.918**	-0.682**	0.891**	-0.392	0.076
-0.259	-0.391	-0.308	0.286	-0.278	-0.285	-0.262
0.853**	0.705**	0.723**	-0.302	0.826**	-0.131	-0.126
0.330	0.353	0.360	0.012	0.012	0.489	-0.671**
	0.917**	0.895**	-0.486	0.944**	-0.293	-0.034
		0.975**	-0.654**	0.955**	-0.194	-0.030
			-0.686**	0.934**	-0.168	0.005
				-0.495	0.267	-0.127
					-0.067	-0.190
						-0.164

ely.

It was apparent that total dry weight/plant (yield capacity potential) was strongly and positively associated with both grain yield/plant and number of days to maturity (Table 2 and Fig. 6a). There was, however, a weak association between growth duration and grain yield/plant (Table 2). Although it is believed that the longer the vegetative and grain filling phases, the greater the probability of high yield in a crop (Bunting and Drennan, 1966; Slatyer, 1970), long duration cultivars are not necessarily efficient in producing high economic yield (grain yield/plant). The following equation, introduced by Nichiporovich (1956), may help to elucidate the relationship between yield capacity potential and actual yield:

$$Y_{econ.} = K_{econ.} \times Y_{biol.}$$

where $Y_{econ.}$ = economic yield (grain yield in cereals)

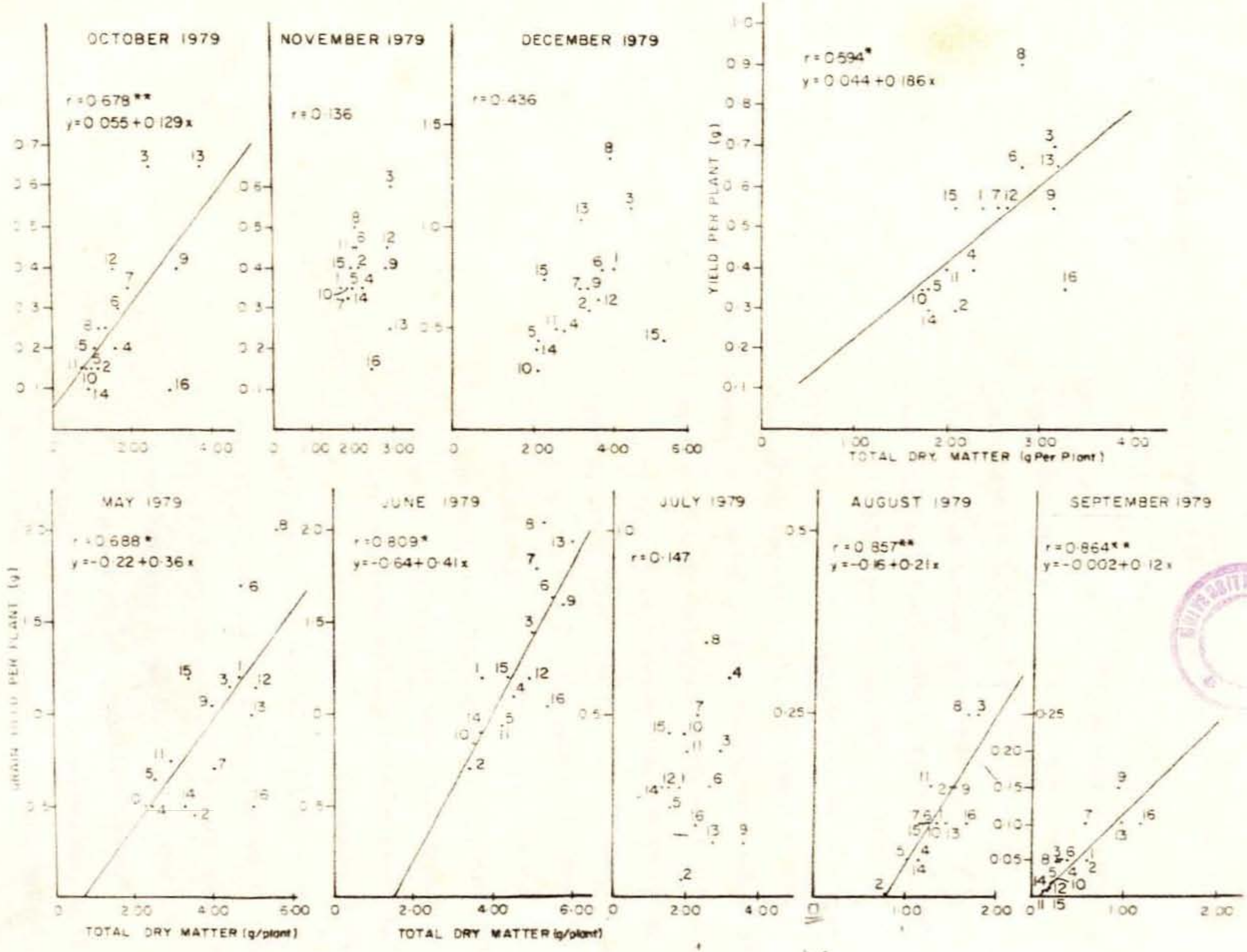
$Y_{biol.}$ = biological yield (total dry matter accumulated) and

$K_{econ.}$ = harvest index (the coefficient of effectiveness of formation of the economic part of total yield.

$K_{econ.}$ is an inherent cultivar character known to differ from cultivar to cultivar (Yoshida, 1972) and expressed through the mediation of environmental factors (Pinthus, 1964). So that $Y_{biol.}$ *per se* does not determine the realisation of $Y_{econ.}$. For example the medium duration cultivars, accessions 3, 6, 7 and 8 of relatively low total dry weight/plant values were significantly higher yielders than the late maturing cultivars, 9, 13 and 16 with higher values of total dry weight/plant.

FIG 6a RELATIONSHIP BETWEEN GRAIN YIELD (PER PLANT) AND TOTAL DRY MATTER (PER PLANT) FOR EACH PLANTING DATE

RELATIONSHIP BETWEEN GRAIN YIELD (PER PLANT) AND TOTAL DRY MATTER (PER PLANT) USING CULTIVAR MEANS FOR ALL PLANTINGS



Thus cultivars 3, 6, 7 and 8 were relatively more efficient than 9, 13 and 16.

(ii) Yield and yield components: Of the yield components, number of seeds per spikelet appeared to be the most important in the determination of grain yield production as was found also by Asana and Williams (1965) and Simmons and Moss (1978). The cultivars 6, 7 and 8 gave the highest recorded values for number of seeds/spikelet, and hence their high values of grain yield/plant (Table 3). Number of spikelets/plant and unit grain weight showed weak association with grain yield, indicating the relatively low importance of these components in grain yield determination (Fig. 6b). The negative, though weak association between grain yield and unit grain weight seems to suggest that the large-seeded cultivars were generally lower yielding than the small-seeded ones as apparent in Table 3. The large-seeded cultivars, 12 and 14 were observed to be lower yielding as compared to the smaller seeded cultivars, 4, 5, 6, 7, 8 and 13.

The strong and negative linear association between the components, unit grain weight and number of seeds/spikelet (Fig. 7) suggests the existence of a

TABLE: 3: OVERALL CULTIVAR MEANS

C U L

CHARACTER	1	2	3	4	5	6	7	8
Total dry wt. per plant(g)	2.40	2.10	3.15	2.30	1.80	2.80	2.55	2.80
Tillering	4.1	3.9	4.3	4.0	3.3	4.2	4.1	4.1
Fertile tilling percentage (%)	70	52	69	60	73	67	71	75
Plant height (cm)	46.3	43.7	49.2	46.5	44.4	46.7	45.6	46.0
No of leaves/ plant at anthesis	21	22	23	21	19	22	22	21
No of days to anthesis	45	52	48	49	46	47	47	46
No of days to maturity	66	70	65	70	66	67	67	65
Lodging score	1.4	1.5	1.4	1.4	1.6	1.6	1.7	1.4
Seed quality score	2.9	3.3	3.2	3.3	3.1	3.1	3.2	3.0
Grain yield/ plant(g)	0.55	0.30	0.70	0.40	0.35	0.65	0.60	0.90
No of seeds per spikelet	1.2	1.0	1.3	1.2	1.2	1.5	1.5	1.7
No of spikelets per plant	48.9	52.9	58.5	53,5	40.8	54.3	47.6	50.8
1000-seed weight(g)	28.5	26.0	27.0	21.0	22.0	21.5	21.0	23.0
Calculated mean grain yield/ plot(kg/ha)	588	320	658	420	523	855	758	1020

ANS FOR THE CHARACTERS STUDIED

JLTIVAR

8	9	10	11	12	13	14	15	16	STANDARD ERROR
0	3.15	1.75	2.00	2.65	3.20	1.80	2.10	3.30	0.1159
	5.4	3.4	3.5	3.5	5.4	3.5	3.9	5.1	0.1768
	72	73	72	78	59	73	69	49	1.7166
0	47.4	34.4	35.7	46.9	43.2	43.5	42.6	42.5	0.7252
	30	14	15	18	28	18	19	27	0. 185
	60	39	39	41	61	43	46	59	0.5554
	78	57	58	62	80	60	64	82	0.5987
4	1.4	1.2	1.3	1.5	1.2	1.3	1.5	1.2	0.0884
0	3.0	3.6	3.7	2.8	3.0	2.8	3.3	3.7	0.0707
90	0.55	0.35	0.40	0.55	0.65	0.30	0.55	0.35	0.0433
.7	1.0	1.0	1.0	0.9	1.4	0.7	1.3	0.7	0.0530
.8	64.9	38.2	42.9	41.9	79.2	43.7	46.5	77.7	3.2370
.0	26.0	28.0	27.0	39.0	[illegible]3.0	33.0	23.5	27.5	0.5590
20	648	313	358	508	673	330	533	305	58.4634

FIG. 6b RELATIONSHIP BETWEEN GRAIN YIELD PER PLANT AND THE COMPONENTS NUMBER OF SEEDS/SPIKELET, NUMBER OF SPIKELETS/PLANT AND UNIT GRAIN WEIGHT

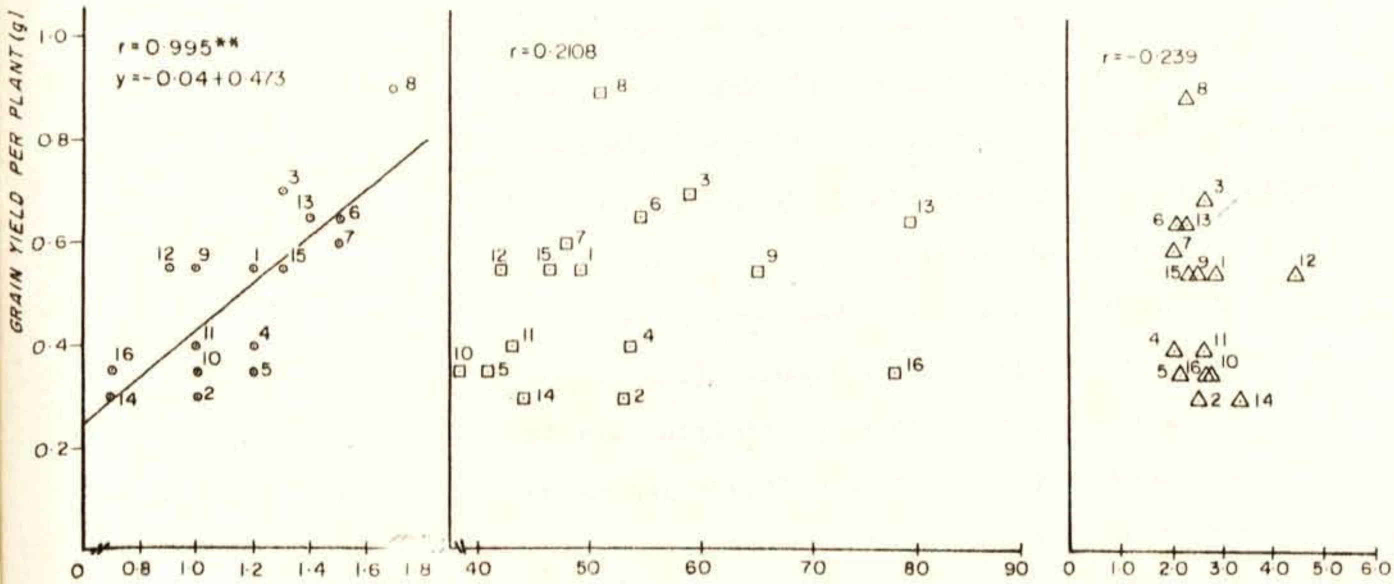
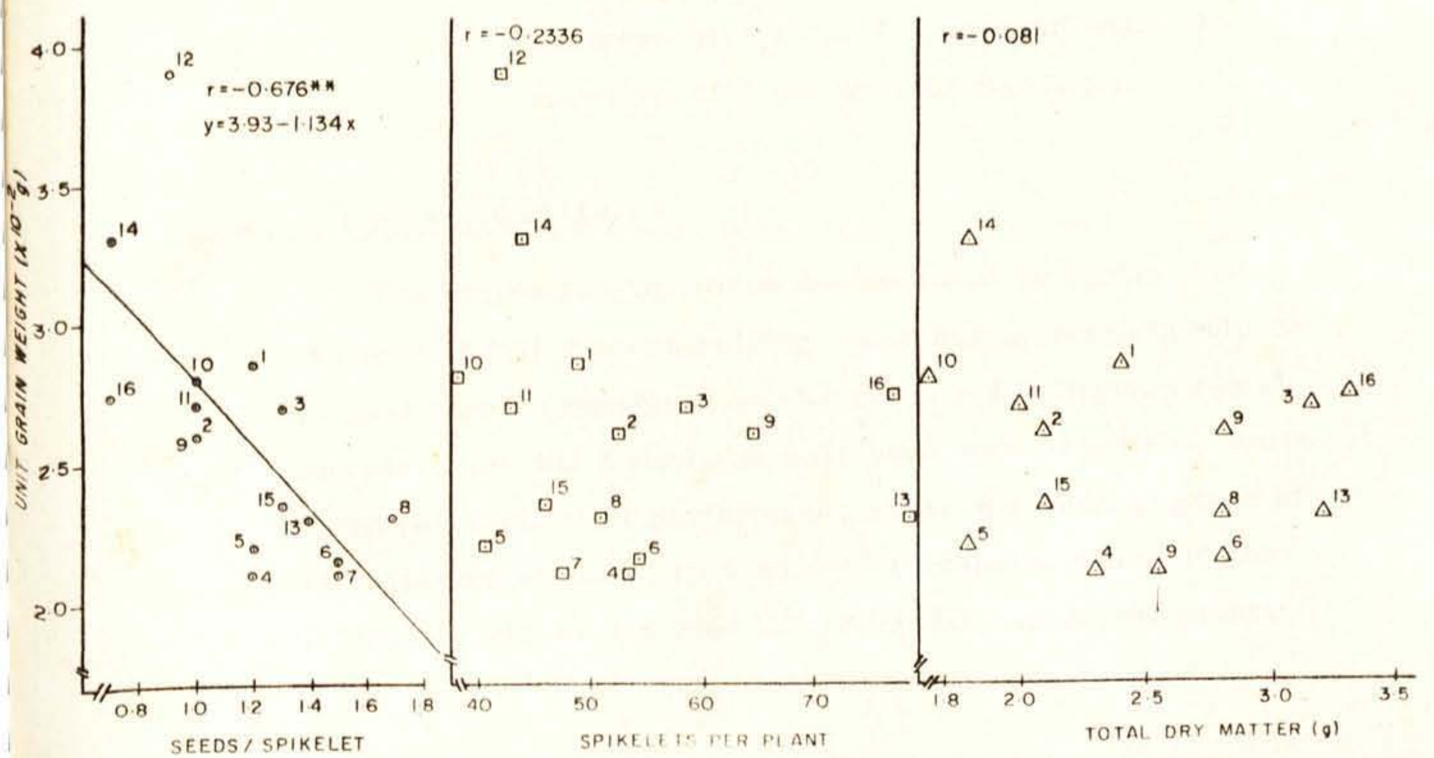


FIG. 7 RELATIONSHIP BETWEEN UNIT GRAIN WEIGHT AND THE CHARACTERS: TOTAL DRY MATTER/PLANT, NUMBER OF SEEDS/SPIKELET AND NUMBER OF SPIKELETS/PLANT



compensatory relationship between them. Such that where seed set was poor, there was generally a production of larger seeds since competition among the seeds for photosynthate is thereby reduced. A similar relationship is known to exist between number of plants/unit area and the extent of tillering in cereals (Pinthus, 1964).

As regards each character studied, Figs. 5(i - xiii) illustrate the relative performance of the cultivars at each planting date. From these illustrations, the planting date mean values seem to give an indication as to the relative favourability of the planting dates to the expression of each character. The most favourable planting date for all cultivars was the June planting, followed by the May and December plantings. The most unfavourable planting date was that of September.

B.Cultivar Adaptability

The regression technique as developed by Finlay and Wilkinson (1963) for determining adaptability among cultivars was used here as described in Materials and Methods. Overall mean yields of the individual cultivars were used as an index of general individual performance, while the average yield of all cultivars at each planting date (including those of the preliminary trial) was used to numerically grade the planting dates thus giving a useful evaluation of the environmental conditions that prevailed during the growth period of each planting.

In this study the basic yields were transformed on a logarithmic scale to induce a reasonable degree of linearity in the regressions as well as some amount of homogeneity in experimental error (Finlay and Wilkinson, 1963). The different types of cultivar response to planting date are illustrated in Fig. 8. The population mean with a regression coefficient of unity (1) is also shown.

Cultivars characterised by regression coefficients of the order 1.0 have average stability over all planting dates (Fig.9). For example cultivars 2, 4, 8 and 13 showed coefficients not significantly different from 1.0 (Table 4) indicating consistent performance in all the plantings; however, the low overall mean yield of cultivar 2 implied that it was poorly adapted to all planting dates. By the same reasoning, cultivar 8 with a high mean yield exhibited consistently high yields at all planting dates and hence was adapted to all planting dates.

The high regression coefficients of cultivars 11 and 14 indicated that they were very sensitive to changes in environment (planting date). These cultivars were observed to produce very low yields at the least favourable planting dates but as favourability (planting date mean values) improved, their yields increased at rates above average for the collection of cultivars, indicating below average stability (Fig. 9).

The S_d^2 values (Table 5) which are a measure of stability as defined by Eberhart and Russel (1966) , also explain the relative stabilities observed. The smaller the value the more

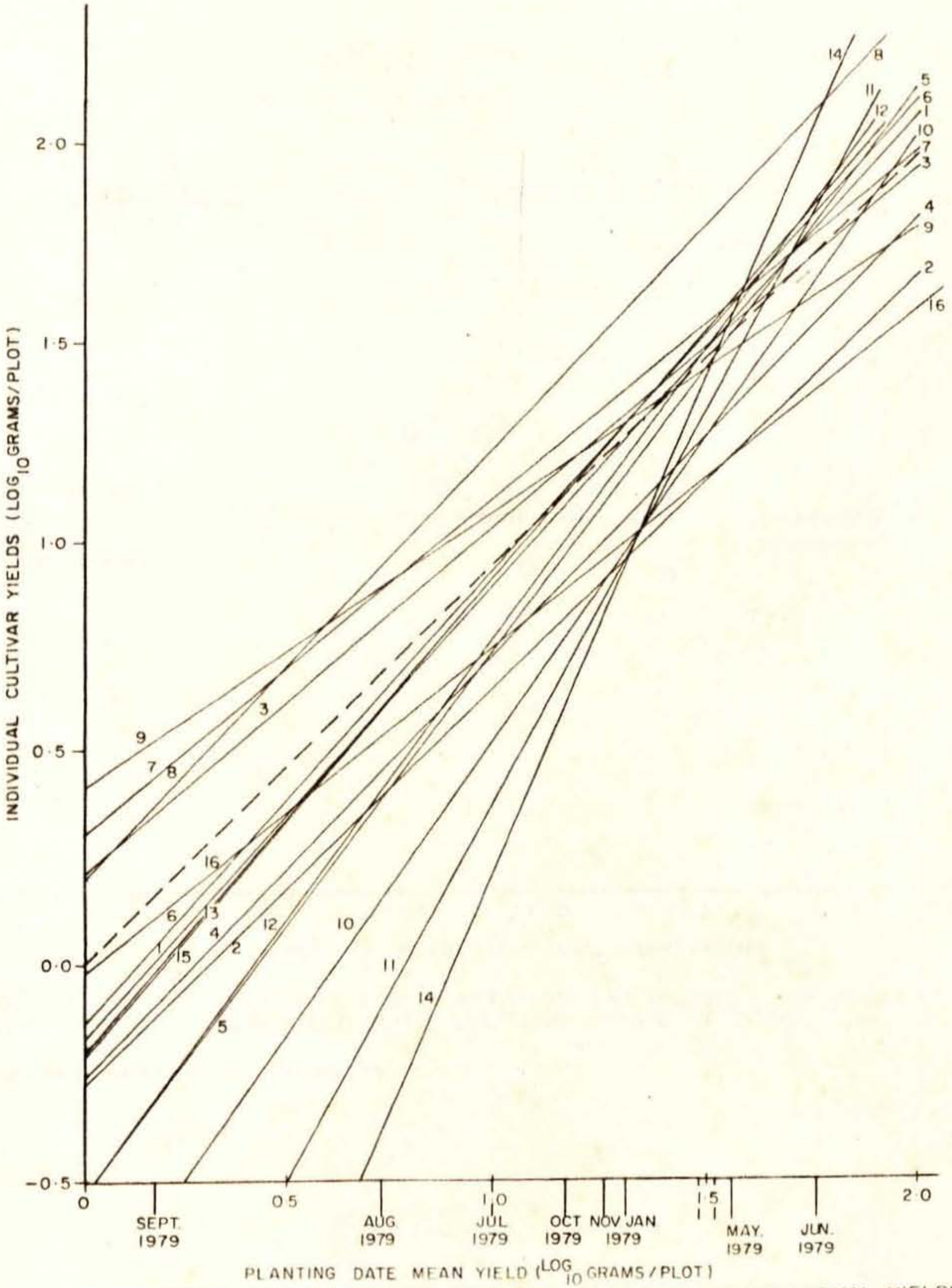


FIG. 8 REGRESSION LINES SHOWING THE RELATIONSHIP OF INDIVIDUAL YIELDS OF 16 CULTIVARS OF WHEAT SOWN AT DIFFERENT PLANTING DATES

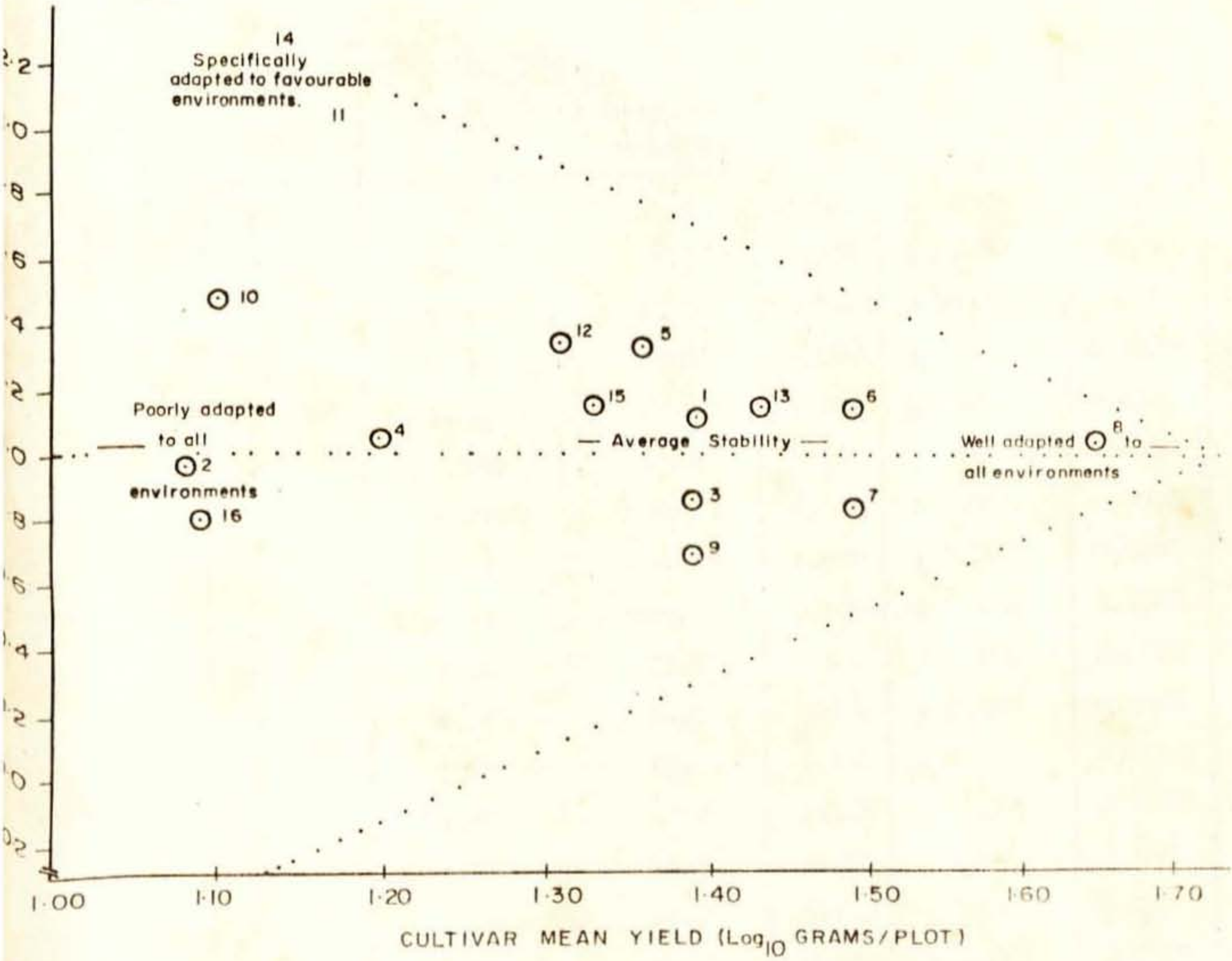


FIG. 9 THE RELATIONSHIP OF CULTIVAR ADAPTATION (REGRESSION COEFFICIENT) AND CULTIVAR MEAN YIELD (WITH CULTIVAR STABILITY MODEL)*

* Adapted from Finlay and Wilkinson (1963)

TABLE 4: MEAN GRAIN YIELD, REGRESSION COEFFICIENTS AND STABILITY PARAMETERS OF 16 CULTIVARS OF COMMON WHEAT, SOWN OVER TEN PLANTING DATES AT KPONG.

CULTIVAR	MEAN GRAIN YIELD (Log_{10} g/plot)	(Absolute values)	b	S.E. of b	S_d^2
1	1.39	24.7	1.121	± 0.066	0.0085
2	1.08	11.9	0.966	± 0.236	0.1078
3	1.39	24.6	0.861	± 0.115	0.0255
4	1.20	16.0	1.047	± 0.212	0.0868
5	1.36	22.9	1.336	± 0.083	0.0132
6	1.149	31.1	1.158	± 0.127	0.0310
7	1.49	30.9	0.866	± 0.068	0.0090
8	1.65	44.9	1.059	± 0.102	0.0200
9	1.39	24.4	0.689	± 0.173	0.0581
10	1.10	12.5	1.485	± 0.182	0.0606
11	1.16	14.3	2.020	± 0.557	0.5655
12	1.31	20.3	1.352	± 0.210	0.0805
13	1.43	26.9	1.143	± 0.243	0.1075
14	1.12	13.3	2.273	± 0.377	0.2586
15	1.33	21.4	1.142	± 0.097	0.0171
16	1.09	12.2	0.798	± 0.113	0.0231

FOOT NOTE:

In the calculations of regressions and stability parameters in the above table, the basic yields were measured on a logarithmic scale (after Finlay and Wilkinson, 1963).

stable the cultivar in that its yield at each planting is closely similar to that predicted by its regression line. Thus cultivars 11 and 14 with the highest observed S_d^2 values were the least stable.

By means of these parameters, the stable (ideal) cultivar is defined as the one with a high overall mean yield, unit regression coefficient (b = 1.0) and minimum deviation from the regression line, i.e. $S_d^2 = 0$ (Eberhart and Russell, 1966). By this definition, cultivars 2 and 16 were observed as the least stable and least adapted to Kpong. The most adapted were cultivars 8, 6 and 7 (in that order) which exhibited high stability. The remaining cultivars exhibited average adaptability and stability. See Fig. 9.

The grading of planting dates, from the most to the least favourable were as follows: June, May, and December (1979) and then followed by December (1978), January, November, October, July, August and September (1979). From this order, the rainy season appeared to be the most favourable period for growing wheat at Kpong. Cheng (1977) has reported similar findings in Taiwan where wheat is sown to catch the cool temperatures afforded by the rainy season in certain locations.

Two other observations could be made from the planting date order of favourability. Firstly, the positions of the December, 1978 and December, 1979 plantings seem to suggest that similar environmental conditions prevailed during the growth of the crop in the two consecutive years, pointing to some generality of the results. Secondly, even though nine cultivars were sown during the preliminary trial as against sixteen cultivars in the other plantings, the evaluation of planting dates by the two sets of cultivars (9 and 16) appeared identical. This is seen in the close positions of the two December plantings , indicating that the regression technique may be reliably used in evaluating environments, irrespective of the number of cultivars sown at particular locations or dates.

V

SUMMARY AND CONCLUSION

1. Planting Date

In a study such as this, in which the crop is subjected to an uncontrolled environment, one cannot be very conclusive in establishing cause-and-effect relationships. It is likely, however, that the slight seasonal variation observed in climatic conditions (characteristic of the Accra Plains) may have caused the significant differences observed due to planting date.

The relatively cool weather and high rainfall that characterised the period from June to September, 1979 (Fig. 4a) may explain why the June planting was observed as the most favourable of the planting dates followed by that of May. The rainfall during this period may have provided adequate moisture in the root zone to supplement the probable loss due to the rapid transpiration known to be associated with high temperatures in heat-sensitive species (Henckel, 1964) such as wheat. Such an adaptation is a means of cooling the plant to prevent thermal injury.

The relatively hot weather that characterised the minor rainy season and the dry season that immediately followed it (August, 1979 to March, 1980) were likely to have led to the poor performance of the crop in the the second and third planting seasons.

2. Cultivars

There were indications that the cultivars differed in their adaptability as seen by the highly significant interaction between planting date and cultivars in almost every character studied. By means of the regression technique, the relative adaptability as well as stability of the cultivars were determined. Cultivars 8, 6 and 7 were the most adaptable (in descending order) as shown in Fig. 9. The least adaptable were cultivars 2 and 16.

3. Potential Cultivars

An ideal cultivar for the Lowland Tropics may be one that will produce stable, high yields under a wide range of environmental conditions, being relatively insensitive to heat and photoperiod. Due to the reduction in plant size, known to be associated with high temperatures in wheat (van Dobben, 1962), a potential cultivar ought to be efficient in converting a high proportion of its biological yield into useful economic product.

In the present study, cultivar 8 was observed as the most adaptable to Kpong (Fig. 9). It gave an overall mean yield of about 1,120 kg/ha while all the other cultivars gave corresponding yields of below 1,000 kg/ha. In addition to cultivar 8, cultivars 6 and 7 could be selected as potentials for Kpong and other locations of similar or cooler climate. The latter two cultivars gave overall mean yields of about 775 kg/ha. Calculated yields of these cultivars at the most favourable planting date (June) were in the range of 2,245 - 2,625 kg/ha.

An examination of the cultivar regression coefficients and other stability parameters as given in Table 4, reveals the potentialities of these three cultivars mentioned above.

Their regression coefficients were not significantly different from 1.0 indicating consistent performance (yields) over all planting dates. The relatively low deviation mean square (S_d^2) values also indicated low sensitivity to environmental changes. Together with these parameters, their relatively high overall mean cultivar yields implied that they produced consistently good yields at all planting dates. Hence, these cultivars were well adapted to the location (Kpong).

These three cultivars (accessions 6, 7 and 8) produced the highest mean number of seeds per spikelet (the most important component of grain yield as was observed in this study) as well. The author would therefore recommend the cultivars, 7423 - K4, 7438 - D and 7438 - X (accessions 6, 7 and 8 respectively) as promising cultivars that are worth considering for any further studies on common wheat in Ghana.

4. Concluding Remarks

It is apparent from the findings of this study that time of planting is an important factor affecting wheat performance in Ghana. For objective conclusions to be drawn, however, on the feasibility of growing wheat on a large scale here, further studies need to be made on the crop.

Such studies should include a repeat of this present study at several locations in the country in order to determine which seasons and locations will afford the most favourable conditions for wheat growth. Locations with facilities for irrigation like Veya (near Bolgatanga) and Tono in the Upper region of Ghana, as well as others with cooler climates (than that of Kpong) like Amedzofe in the Volta region should be included in such a study.

Since wheat, like other heat-sensitive species, is known to transpire excessively in hot environments as a means of cooling the plant against thermal injury (Henckel, 1964), the author recommends that alongside field experiments in different locations, greenhouse experiments be conducted also in which regulated quantities of water are supplied to each plant. This would help to ascertain whether or not a good supply of water (at ambient temperatures here) would sustain any excessive transpiration without moisture stress and possibly improve wheat performance and yield.

Alongside the cultivars recommended in this thesis, more cultivars should be evaluated in such studies, especially some of the cultivars recommended for their supposedly good performance in warmer regions (from Pakistan, Mexico (CIMMYT) and India). Criteria for selecting promising cultivars from such studies should include resistance or tolerance to the most important crop diseases in Ghana.

The author is of the opinion that though it is too early, on the basis of the results of the present study, to conclude that wheat will thrive in Ghana, it is yet too early to write the crop off altogether.

Considering Ghana's foreign exchange expenditure on wheat importation alone (Appendix I) all avenues, including mutation breeding, should be explored before giving up on the crop.

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APPENDIX 1.

Wheat imports (grain and/or flour) into Ghana from 1961-1979.

YEAR	TONNAGE(mt)	COST PER METRIC TONNE	TOTAL COST
1961	62,644.09	£G 49.74	£G 3,115,781.00
1962	50,145.33	£G 55.94	£G 2,805,192.00
1963	32,562.95	£G 52.18	£G 1,699,135.00
1968	59,450.67	N¢136.92	N¢ 8,139,755.00
1969	62,810.65	N¢113.30	N¢ 7,116,690.00
1971	40,956.08	¢ 87.46	¢ 3,582,211.00
1972	87,540.69	¢ 99.69	¢ 8,736,786.00
1975	83,302.09	¢269.79	¢22,473,757.00
1977	140,359.00 x 130,359.00	¢376.71	¢49,107,825.25
1978	116,913.00 x 102,453.00	¢445.87	¢45,680,995.25
1979	124,289.00 x 74,736.00	¢492.87	¢36,835,361.05

x Total amount paid for (remainder being aid from Canada and U.S.A.).

(Source of above figures: 1961 - 1975 = Central Bureau of statistics, Accra.; 1977 - 1979 = Ghana National Procurement Agency, Accra.

APPENDIX 11: HEAT UNIT SUMMATIONS FOR WHEAT SHOWING NEAR CONSTANCY

GROWTH PHASE IN DIFFERE

(A) HEAT UNIT SUMMATIONS FOR NP WHEAT(FRO

STATION	LAT. °N		LONG °E		AVERAGE DATES OF: SOWING	COMMENCEMENT OF FLOWERING	COMPLETION FLOWERIN
Dharwar	15°	26'	75°	06'	22nd Oct.	10th dec.	26th Dec
Parbhani	19	16	76	47	10th Oct.	6th December	1st Januar
Niphad	20	06	74	07	26th Oct.	20th Dec.	2nd Januar
Jalgaon	21	03	75	34	23rd Oct.	14th Dec.	28th Dece
Nagpur	21	09	79	22	30th Oct.	27th Dec.	12th Jan.
Lalhandi	21	16	81	30	19th Nov.	18th Jan.	9th Feb.
Pavarkhera	22	44	77	42	31th Oct	1st Jan.	18th Jan
Chirisurah	22	52	88	24	11th Oct	13th Feb	2nd March
Kanpur	26	28	80	21	6th Nov.	19th Jan.	7th Feb.
Aligarh	27	50	78	10	1st Nov.	20th Jan.	11th Feb
Delhi	28	40	77	10	11th Nov	8th Feb	1st March

ISTANCY IN TOTAL HEAR UNITS REQUIRE BY EACH

DIFFERENT COUNTRIES

EAT (FROM VENKATARAMAN AND KAZI, 1972)

PLETION OF 'LOWERING	HEAT UNIT ACCUMULATIONS AND AVERAGE TEMPERATURE (°C) IN THE PHASE			
	SOWING TO EAR EMERGENCE		EAR EMERGENCE PHASE	
th Dec	934 h.u.	(22.2 C)	315 h.u.	(23.7 C)
January	1,069	(23.0)	486	(22.6)
January	936	(20.8)	252	(23.4)
th December	1,053	(23.7)	303	(25.6)
h Jan.	1,001	(20.9)	256	(20.0)
h Feb.	960	(20.0)	427	(23.4)
h Jan	965	(19.6)	260	(19.3)
d March	939	(18.0)	305	(22.0)
h Feb.	1,005	(17.0)	247	(17.0)
h Feb	967	(18.8)	182	(12.3)
t March	970	(17.5)	241	(14.1)

APPENDIX II

(b) Summations of "heat unit" requirements of spring wheat in North America, the Soviet Union and Finland.

COUNTRY & PERIOD OVER WHICH MEAN FOR SUMMATION OF HEAT UNITS WAS DONE.	HEAT UNITS (°F)		
	Sown to headed	Headed to ripe	Sown to ripe
U.S.A. (168 crop years)	1,142	968	2,110
CANADA (195 crop years)	983	973	1,9[illegible]
U.S.S.R. (150 crop years)	1,123	1,030	2,183
FINLAND (163 crop years)	866	984	1,832
	Coefficients of variation (per cent)		
U.S.A.	9.4	5.0	6.3
CANADA	7.6	4.1	5.3
U.S.S.R.	10.1	7.7	6.3
FINLAND	5.1	7.1	5.9

(from Nuttonson, (1955)).

APPENDIX III: METEOROLOGICAL DATA FOR UNIVERSITY OF GHANA'S AGRICULTUR

(WITH AVER

	DEC.	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY
Rainfall (mm)	47	2	83	11	19	238	171	173
Average for 21 years	36	21	33	115	136	158	218	90
Average day length over the years. (hours)	11.8	11.8	11.9	12.1	12.2	12.3	12.4	12.3
Relative humidity (0900GMT) %	78	77	71	76	71	75	79	80
Average for 16 years	80	81	74	72	77	77	80	79
Relative humidity (1500 GMT) %	64	60	60	70	57	64	71	78
Average for 16 years	58	52	52	58	64	67	74	71
Mean maximum temp. (°C)	34	38	36	35	35	33	32	30
Average for 16 years	33	33	36	35	34	33	31	30
Mean minimum temp. (°C)	22	23	24	24	24	23	23	22
Average for 16 years	22	21	23	23	23	23	22	22
Mean daily temperature (°C)	28.1	29.2	29.7	29.4	29.7	28.1	27.5	26.1
Average for 16 years	26.9	27.2	29.2	29.2	28.6	28.1	26.7	25.8

URAL RESEARCH STATION AT KPONG, DECEMBER1978-MARCH 1980
ERAGES OVER THE YEARS)

Y	AUG.	SEPT	OCT.	NOV	DEC.	JAN	FEB.	MARCH
3	26	299	69	49	1	29	40	58
0	56	126	148	100				
3	12.3	12.1	12.0	11.9				
0	76	75	77	75	60	76	72	68
9	75	77	78	77				
8	63	68	69	64	54	50	52	56
1	68	69	69	65				
0	31	32	33	34	33	35	35	35
0	30	31	32	33				
2	22	21	22	22	22	23	24	24
2	22	22	23	22				
1	26 1	25.4	27.2	27 8	27.2	28 7	29.6	29.7
8	25.8	26.4	26.9	27.2				

CONT'D ON THE NEXT PAGE

APPENDIX 111(F): SOME METEOROLOGICAL DATA FOR AMEDZOFE (VOLTA REGION)

(1) AMEDZOFE(1971)	JAN	FEB	MAR.	APRIL	MAY
Mean Maximum temp. (°)	27.6	29.1	28.6	29.6	27.2
Average for 10 years Mean Minimum temp. (°c)	19.9	20.1	20.4	20.3	19.9
(2) ATEBUBU(1971)					
Mean Maximum temp. (°C) (for 1976)	33.9	35.5	35.2	34.2	33.3
Mean Minum temp. (°C)	18.4	22.3	22.3	22.0	22.4
(3) MANGA(1971)					
Mean Maximum temp. (°C)	34.5	37.9	38.5	38.3	36.0
Mean Minimum temp. (°C)	16.6	21.0	25.4	25.9	25.4

ION), ATEBUBU(BRONG AHAFO REGION) AND MANGA(UPPER REGION)

MAY	JUNE	JULY	AUG	SEPT.	OCT	NOV	DEC.
27.2	25.0	23.7	23.1	24.1	25.9	27.1	26.8
19.9	19.0	18.1	18.3	18.4	19.1	19.2	20.0
33.3	31.4	30.5	30.8	31.9	31.7	32.7	32.3
22.6	21.3	20.9	21.6	21.7	22.2	21.5	19.6
36.0	33.8	30.6	29.9	30.7	34.2	36.7	34.1
25.4	23.2	22.4	22.3	22.1	21.7	18.7	19.2

APPENDIX III

CONT'D

	DEC.	JAN	FEB.	MAR.	APRIL	MAY	JUNE
2" earth temp. (°C) 0900 GMT	30.7	30.3	30.7	32.1	33.6	31.5	30.2
Average for 13 years	27.7	27.7	29.1	29.4	29.1	29.7	28.3
2" earth temp (°C) 1500 GMT	39.2	41.2	42.7	40.1	42.4	37.8	33.1
Average for 13 years	32.5	33.2	35.3	35.4	34.4	34.0	31.4
Average daily solar radiation* in a cloudless sky (cal/cm^2)	606	623	729	690	700	652	663
Mean daily sunshine (%)	65%	60	64	59	57	57	40

* Figures from Riley (1979) for latitude 6° N.

JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN	FEB	MARCH
30.2	-	25.5	28.1	28.0	27.8	27.5	-	-	-
28.3	27.3	27.1	27.3	27.6	27.7				
33.1	-	34.2	33.4	34.3	33.7	34.2	-	-	-
31.4	30.8	30.8	31.7	32.1	31.7				
663	645	645	710	664	650	606			
40	35	37	41	58	65	65			

APPENDIX IV

(a) Heat unit summations for 16 cultivars of common bread wheat sown over ten planting dates (showing mean heat units (°C) and coefficient of variation (C.V.)).

CULTIVAR	Emergence to anthesis		Anthesis to maturity		Emergence to maturity	
	Mean(°C)	C.V.(%)	Mean(°C)	C.V.(%)	Mean(°C)	C.V.(%)
1	936	10.6	534	23.3	1,588	13.2
2	1,207	11.5	433	12.8	1,696	9.0
3	1,139	10.5	445	12.6	1,582	11.8
4	1,209	14.4	465	13.8	1,697	12.0
5	1,083	10.1	506	18.3	1,590	12.0
6	1,158	15.7	499	19.6	1,657	14.5
7	1,094	7.5	528	27.6	1,621	13.0
8	1,116	13.4	468	18.4	1,586	12.5
9	1,437	8.7	429	11.9	1,863	8.1
10*	899	8.2	418	19.8	1,317	8.9
11*	890	10.8	447	11.9	1,336	9.7
12*	959	8.7	477	21.5	1,436	10.2
13*	1,416	10.0	454	15.4	1,871	9.5
14*	983	8.6	406	15.2	1,388	9.0
15*	1,068	8.4	413	16.2	1,481	6.8
16*	1,373	15.9	548	17.1	1,921	12.5

Note: Mean heat units were computed from daily accumulations (determined by the mean daily temperature minus 4°C).

* Cultivars that were sown over eight (8) planting dates only.

APPENDIX IV

(b) Mean heat unit summations for 16 cultivars of common bread wheat at ten (10) planting dates (with coefficients of variation (%)).

PLANTING DATE	Emergence to anthesis Mean(°C)	Anthesis to maturity Mean(°C)	Emergence to maturity Mean(°C)
19th Dec., 1978	1,337	605	1,942
19th Jan., 1979	1,310	538	1,848
23rd May, "	1,243	563	1,806
20th June, "	1,084	494	1,578
16th July, "	1,026	398	1,423
20th August "	1,019	364	1,383
25th Sept., "	1,203	441	1,644
22nd Oct., "	1,129	433	1,563
23rd Nov., "	1,001	472	1,473
13th Dec., "	1,193	553	1,671
Coefficient of variation (%)	10.5	16.1	11.4

APPENDIX V. GRAIN YIELDS(g/plot)OF 16 CULTIVARS OF WHEAT GROWN AT KPONG OVER TEN PLANTING DATES

CULTIVAR	PLANTING DATES										
	Dec. 1978	Jan. 1979	May 1979	June 1979	July 1979	Aug. 1979	Sept 1979	Oct. 1979	Nov. 1979	Dec. 1979	OVERALL MEAN
1	30.2	28.8	48.1	62.3	7.2	4.5	1.3	10.2	18.2	36.5	24.7
2	10.4	663	19.4	29.7	7.3	0.5	1.8	5.4	14.8	23.7	11.9
3	21.0	10.9	41.9	60.8	13.0	9.7	1.9	27.2	23.5	36.1	24.6
4	16.4	9.4	25.3	42.9	17.9	0.8	1.4	7.0	12.2	27.0	16.0
5	35.1	26.9	30.3	71.8	5.4	4.3	0.5	8.1	15.2	31.7	22.9
6	20.1	17.2	66.3	97.9	9.9	3.0	1.6	25.7	26.3	43.3	31.1
7	39.3	27.8	44.3	89.8	20.4	6.7	3.4	21.5	18.0	38.1	30.9
8	76.9	45.3	77.5	105.0	23.8	17.0	1.8	17.5	32.8	51.2	44.9
9	23.7	12.3	44.9	55.0	4.2	7.0	6.4	21.0	22.5	46.7	24.4
10	-	-	21.0	32.3	4.2	4.0	0.1	8.9	10.1	19.0	12.5
11	-	-	11.7	26.2	15.1	8.2	0.05	7.8	19.5	26.2	14.3
12	-	-	41.9	48.9	2.6	8.6	0.3	16.0	14.0	31.2	20.3
13	-	-	32.1	73.8	2.3	3.9	1.5	39.9	12.2	49.6	26.9
14	-	-	15.7	40.9	6.8	1.4	0.05	3.5	20.5	17.2	13.3
15	-	-	35.9	45.5	13.1	4.4	0.8	10.4	24.7	36.0	21.4
16	-	-	22.1	37.1	7.3	3.3	1.8	5.3	6.8	14.0	12.2
Planting Date Mean	30.3	20.5	36.2	57.4	10.0	5.5	1.5	14.7	18.2	33.0	
S.E. ±	6.56	4.21	4.50	6.11	1.63	1.03	0.40	2.53	1.68	2.84	

Foot note: To transform absolute yields (g/plot) into calculated yields (kg/ha), multiply absolute quantity by 25. Harvested plot size = $0.4m^2$.

APPENDIX VI: ANALYSIS OF VARIANCE FOR THE EFFECT OF PLANTING DATE ON A

AT KPONG. (A) DECEMBER, 1978 STARTI

M E A N S Q U A R

Source of variation	d.f	Tillering rate	Fertile tillering percentage	No of seeds/spikelet	N
TOTAL	35				
Replicates	3	1.62	979.29**	0.05	
Cultivars	8	1.00	539.56**	0.55**	
Errors	24	1.10	89.77	0.07	

** Indicate significance of P= 0.05 a

(B) JANUARY,1979 PLA

MEAN SQU

Source of Variation	d.f.	Tillering rate	Fertile tillering percentage	No of seeds/spikelet	No
TOTAL	35				
Replicates	3	2.24	17.07	0.10	
Cultivars	8	1.27	240.09	0.44**	
Error	24	0.81	121.39	0.05	

*and ** indicate significance at P =

ON ALL THE CHARACTERS STUDIED IN (9 CULTIVARS OF WHEAT

ARTING(PRELIMINARY TRIAL)

A R E S(MS)

	No of spikelets per head	Grain yield per plant	Plant height	Lodging score	No. of days to anthesis	No. of days of to maturity
	1.05	0.28	69.39**	0.33	15.44	0.62
	4.66**	1.11**	61.32**	1.30**	201.31**	64.38**
	0.74	0.12	12.75	0.35	8.25	7.91

05 and 0.01 respectively.

PLANTING(PRELIMINARY TRIAL)

SQUARES (MS)

	No. of spikelets per head	Grain yield per plant	Plant height	Lodging Score	No of days to anthesis	No of days to maturity
	1.46	0.08	19.89	0.37	6.26	3.14
	6.75**	0.36	23.42	0.61*	175.65	61.07**
	0.63	0.34	16.51	0.20	4.47	2.10

P = 0.05 and 0.01 respectively

APPENDIX VII ANALYSIS OF VARIANCE FOR THE EFFECT OF PLANTING DATE ON A

(A) MAY, 1979 PLA

MEAN SQUARES (

Source of variation	d.f.	Total dry wt/plant 1	Tillering rate 2	Fertile tillering percentage	No of leaves at anthesis	Plant height	N d a
Total	63	2.77					
Replicate	3	2.77	0.88	212.83	11.29	13.02	
Cultivar	15	3.90**	3.10	667.37**	90.75**	169.82**	[illegible]
Error	45	0.34	1.78	147.51	16.99	31.07	

* and ** indicate significance

(B) JUNE, 1979 PLANTIN

Source of Variation	d f.	Total dry wt/plant	Tillering rate	Fertile tillering percentage	No. of leaves/ plant at anthesis	Plant height	N d a
Total	63						
Replicate	3	0.77	9.74**	482.02	65.71	72.89*	
Cultivar	15	2.74**	3.37*	334.39**	125.47**	142.56**	1
Error	45	1.37	1.77	87.14	40.46	19.69	

* and ** indicate significance

N ALL CHARACTERS STUDIED IN 16 CULTIVARS OF WHEAT AT KPONG

PLANTING
S (MS)

No of days to anthesis	No of days to maturity	Lodging score	Seed quality score	Grain yield per plant	No of seeds per spikelets	No of spikelets/ plant	1000-seed Weight
28.43	21.31	0.27	0.44	0.76	0.10	201.59	8.00
359.27	250.47**	0.59*	1.06**	0.84**	0.32	911.78	57.00**
23.54	13.58	0.29	0.33	0.19	0.03	332.73	4.00

nce at P = 0.05 and -.01 respectively

ING MEAN SQUARES (MS)

No of days to anthesis	No. of days to maturity	Lodging score	Seed quality score	Grain yield per plant	No. of seeds per spikelet	No of spikelets per plant	1000-seed weight
15.42	8.54	0.38?	0.39	0.25	0.23?	3996.77**	22.00**
146.22**	148.76**	0.55**	0.83**	0.76*?	0.75**	1688.39**	90.00**
11.38	8.11?	0.14	0.20	0.38?	0.08	567.68	3.00

ce at P = 0.05 and 0.01 respectively.

APPENDIX VII (cont'd)

(C) JULY, 1979 PLANT

MEAN SQUARES

Source of variation	d.f.	Total dry wt/plant	Tillering rate	Fertile tillering percentage	No of leaves/ plant at anthesis	plant height	No of days anthe
Total	63						
Replicates	3	3.34	0.21	213.31	77.05	238.43**	58.
Cultivars	15	1.93	6.63**	873.45**	262.53**	73.15**	308.
Error	45	1.25	2.12	265.52	44.89	25.58	17.

* and ** indicate significance

(D) AUGUST, 1979 PL

MEAN SQUARES

Source of variation	d.f.	Total dry wt/plant	Tillering rate	Fertile tillering percentage	No. of leaves/ plant at anthesis	Plant height	No. days anthe
TOTAL	63						
Replicates	3	0.24	1.66**	524.81**	20.27	81.29**	26.
Cultivars	15	0.31	0.83**	319.22**	92.17**	56.75**	150.
Error	45	0.21	0.35	197.72	27.57	15.63	5.

* and ** indicate significanee

PLANTING

UARES

No of days to anthesis	No of days to maturity	Lodging Score	seed quality score	Grain yield per plant	No of seeds per spikelet	No of spikelets per plant	1000-seed weight
58.43*	58.39**	1.02*	0.11	0.17	0.24	98.82	7.00
308.98**	267.23**	0.46	0.45**	0.12	0.71**	1451.39**	90.00**
17.59	9.08	0.34	0.09	0.03	0.12	401.84	8.00

cance of P=0.05 and 0.01 respectively.

979 PLANTING

UARES

No. of days to anthesis	No. of days to maturity	Lodging score	Seed quality score	Grain yield plant	No of seeds per spikelet	No. of spikelets per plant	1000-seed weight
26.29	7.42		0.04	0.01	0.17	367.25**	4.00
150.50	152.67**		0.49	0.02	0.35**	111.43	44.00**
5.79	5.51		0.14	0.01	0.11	83.86	10.00

icanee at P=0.05 and 0.01 respectively.

APPENDIX VII CONT'D

(E) SEPTEMBER, 19

MEAN SQ

Source of Variation	d.f.	Total dry wt/plant	Tillering rate	Fertile Tillering percentage	No. of leaves per plant at anthesis	plant weight	No. days anth
Total	63						
Replicates	3	0.26*	2.40*	240.68	0.43	27.72*	99
Cultivar	15	0.43**	1.90*	436.29**	8.95	70.37**	299
Error	45	0.08	0.82	238.78	2.52	7.54	20

* and ** indicate significanc

(F) OCTOBER, 19

MEAN SQ

Source of variation	d.f.	Total dry wt/plant	Tillering rate	Fertile tillering percentage	No of leaves per plant at anthesis	Plant weight	No. day ant
TOTAL	63						
Replicates	3	4.94**	0.63	394.64**	43.60	353.53**	3
Cultivars	15	3.33**	1.89	621.80**	117.66**	125.26**	29
Error	45	0.36	0.56	92.23	16.89	17.60	(

* and ** indicate significan

1979 PLANTING

SQUARES

o. of ys to nthesis	No. of days to maturity	Lodging score	seed quality score	Grain yield per	No. of seeds per spikelet	No. of spikelets per plant	1000-seed weight
99.89	136.85**	0.60*	0.14	0.01**	0.25*	382.72	10.00
99.56**	442.00**	0.16	0.37*	0.01**	0.69**	389.57**	82.00
20.11	31.43	0.19	0.19	0.02	0.07	137.92	7.00

ance at P = 0.05 and 0.01 respectively.

1979 PLANTING

SQUARES

No. of days to anthesis	No of days to maturity	Lodging score	Seed quality score	Grain yield per	No of seeds per spikelet	No of spikelets per plant	1000-seed weight
39.42**	9.47	0.21	0.02	0.42**	0.52**	309.79	43.00**
292.38**	351.37**	0.15	0.27**	0.11	0.41**	305.48	77.00**
6.79	13.55	0.15	0.07	0.04	0.04	220.37	7.00

cance at P = 0.05 and 0.01 respectively

APPENDIX VII (cont'd)

(G) NOVEMBER, 19

MEAN SQUA

Source of Variation	d.f.	Total dry wt/plant	Tillering rate	Fertile tillering percentage	No. of leaves per plant at anthesis	Plant weight	No. of days anth
TOTAL	63						
Replicates	3	1.14**	1.15	165.10*	15.56	16.22	10
Cultivars	15	0.71**	1.68*	260.43**	35.40	47.33**	127
Error	45	0.23	0.69	51.75	15.66	14.05	5

* and ** indicate significa

(H) DECEMBER, 19

MEAN SQ

Source of Variation	d.f.	Total dry wt/plant	Tillering rate	Fertile tillering percentage	No of leaves per plant at anthesis	Plant weight	No. days anth
TOTAL	63						
Replicates	3	0.36	2.51	11.29	26.63	78.00	28
Cultivars	15	3.40**	5.63**	325.93	179.90**	85.70	13
Error	45	0.66	2.03	63.34	55.66	10.80	5

* and ** indicate significance a

1979 PLANTING

QUARES

Io of ays to nthesis	No. of days to maturity	Lodging score	Seed quality score	Grain yield per	No. of seeds per spikelet	No. of spikelets per plant	1000-seed weight
10.29	17.06	1.85**	0.15	0.08*	0.13	320.73	2.00
127.18	181.62	0.56*	0.87**	0.04*	0.55**	261.15	67.00**
5.54	10.90	0.27	0.22	0.02	0.16		2.00

icance at P = 0.05 and 0.01 respectively

1979 PLANTING

SQUARES

No. of ays to nthesis	No. of days to maturity	Lodging score	Seed quality score	Grain yield per	No. of seeds per spikelet	No. of spikelets per plant	1000-seed weight
28.43*	1.38	0.13	0.01	0.25*	0.59**	667.81	18.00**
138.97**	252.67**	0.05	0.86**	0.20	0.62**	236.40	85.00
5.35	11.15	0.06	0.11	0.08	0.11	678.17	4.00

e at P = 0.05 and 0.01 respectively.

APPENDIX VIII: Analysis of Variance Tables for All Characters Studied.

1. Analysis of variance table for total dry weight/plant

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replicates (R)	3	0.99	0.33	0.77
Cultivars (Cv)	15	145.19	9.01	21.00
Error(a) (R.Cv)	45	19.13	0.43	
Whole units	63	155.31		
Plantings (P)	7	873.78	124.83	192.04^{xx}
Plantings X Reps (P.R)	21	41.04	1.95	3.00^{xx}
Plantings X Cultivars (P.Cv)	105	116.05	1.11	1.71^{xx}
Error (b)	315	205.69	0.65	
TOTAL	511	1391.87		

^{xx} (P = 0.01)

2. Analysis of variance table for grain yield/plant

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replicates(R)	3	0.25	0.08	1.33
Cultivars(Cv)	15	13.90	0.93	15.50xx
Error (a)	45	2.64	0.06	
Whole units	63	16.79		
Plantings (P)	7	82.43	11.78	117.80xx
P X R	21	6.14	0.29	2.90xx
P X Cv	105	18.78	0.18	1.80xx
Error (b)	315	31.52	0.10	
TOTAL	511	155.66		

3. Analysis of variance table for number of seeds/spikelet

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replicates(R)	3	0.15	0.05	0.56
Cultivars (Cv)	15	30.99	2.00	20.00xx
Error (a)	45	4.24	0.09	
Whole units	63	43.38		
Plantings(P)	7	19.11	2.73	27.30xx
P X R	21	6.40	0.30	3.00xx
P X Cv	105	27.00	0.28	2.80xx
Error (b)	315	31.83	0.10	
TOTAL	511	127.72		

xx (P = 0.01)

4. Analysis of variance table for number of spikelets/plant

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replicates(R)	3	1915.66	638.66	1.90
Cultivars (Cv)	15	71608.96	4773.93	14.24^{xx}
Error (a)	45	15088.57	335.30	
Whole units	63	88613.19		
Plantings(P)	7	228095.60	32585.09	97.43^{xx}
P X R	21	17121.22	815.30	2.44^{xx}
P X Cv	105	44067.47	419.69	1.25^{xx}
Error (b)	315	105354.73	334.46	
TOTAL	511	483252.21		

5. Analysis of variance for 1,000-seed weight

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replicates(R)	3	22.00	7.30	0.73
Cultivars (Cv)	15	10913.00	727.50	72.80^{xx}
Error (a)	45	433.00	10.00	
Whole units	63	11368.00		
Plantings(P)	7	9983.00	1426.14	23.29^{xx}
P X R	21	515.00	24.52	0.40
P X Cv	105	3019.00	28.75	0.47
Error (b)	315	19292.10	61,24	
TOTAL	511	44177.10		

^{xx} (P = 0.01)

6. Analysis of variance table for grain yield/plot

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replicates(R)	3	1638.00	546.00	3.12^{x}
Cultivars(Cv)	15	34218.31	2281.22	13.04^{xx}
Error (a)	45	7875.17	175.00	
Whole units	63	43731.48		
Plantings(P)	7	159162.71	22737.53	143.41^{xx}
P X R	21	17962.23	855.34	5.39^{xx}
P X Cv	105	41330.21	393.62	2.48^{xx}
Error (b)	315	49943.96	158.55	
TOTAL	511	312130.59		

7. Analysis of variance table for tillering rate

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replicates(R)	3	5.20	1.73	1.73
Cultivars(Cv)	15	217.90	14.53	14.53^{xx}
Error (a)	45	45.05	1.00	
Whole units	63	268.15		
Plantings(P)	7	616.91	88.13	67.79^{xx}
P X R	21	54.14	2.58	1.98^{x}
P X Cv	105	157.65	1.50	1.15
Error (b)	315	410.04	1.30	
TOTAL	511	1506.09		

^{x} and ^{xx} (P = 0.05 and 0.01 respectively).

8. Analysis of variance table for fertile tillering percentage

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replicates(R)	3	348.37	116.12	1.23
Cultivars(Cv)	15	33697.65	2246.51	23.82[xx]
Error (a)	45	4243.54	94.30	
Whole units	63	38289.56		
Plantings(P)	7	12684.33	1812.05	13.79[xx]
P X R	21	6526.67	310.79	2.37[xx]
P X Cv	105	23885.46	227.48	1.73[xx]
Error (b)	315	41381.66	131.37	
TOTAL	511	122767.68		

9. Analysis of variance table for number of leaves/plant at anthesis

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replicates(R)	3	50.79	16.93	0.79
Cultivars(Cv)	15	9252.44	616.83	28.77[xx]
Error (a)	45	964.86	21.44	
Whole units	63	10268.09		
Plantings(P)	7	20570.89	2938.70	103.42[xx]
P X R	21	734.60	34.98	1.23
P X Cv	105	4456.39	42.44	1.49[xx]
Error (b)	315	8950.30	28.41	
TOTAL	511	44980.47		

xx $(P = 0.01)$

10. Analysis of variance table for plant height

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replicates(R)	3	10.26	3.42	0.20
Cultivars(Cv)	15	7615.93	507.73	30.17^{xx}
Error (a)	45	757.32	16.83	
Whole units	63	8383.51		
Plantings(P)	7	58753.51	8393.40	477.98^{xx}
P X R	21	2633.05	125.38	7.14^{xx}
P X Cv	105	4018.50	38.27	2.18^{xx}
Error (b)	315	5531.56	17.56	
TOTAL	511	79320.45		

11. Analysis of variance table for number of days to anthesis

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replicates(R)	3	245.80	81.93	8.30^{xx}
Cultivars(Cv)	15	23421.94	1561.46	158.20^{xx}
Error (a)	45	444.01	9.87	
Plantings(P)	7	5407.06	772.44	62.70^{xx}
P X R	21	674.02	32.10	2.60^{xx}
P X Cv	105	3924.00	37.37	3.03^{xx}
Error (b)	315	3880.67	12.32	
TOTAL	511	37997.50		

^{xx} (P = 0.01)

12. Analysis of variance table for number of days to maturity

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replicates(R)	3	199.35	66.45	5.97xx
Cultivars(Cv)	15	16320.80	1754.72	157.66xx
Error (a)	45	500.84	11.13	
Plantings(P)	7	15385.87	2197.98	166.89xx
P X R	21	581.90	27.71	2.14xx
P X Cv	105	4380.07	41.71	3.17xx
Error (b)	315	4146.41	13.17	
TOTAL	511	51517.24		

13. Analysis of variance table for lodging score

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replicates(R)	3	0.31	0.10	0.40
Cultivars(Cv)	15	9.44	0.63	2.52xx
Error (a)	45	11.23	0.25	
Whole units	63	20.98		
Plantings(P)	6	31.09	5.18	25.90xx
P X R	18	13.05	0.73	3.65xx
P X Cv	90	28.49	0.32	1.60xx
Error (b)	270	53.66	0.20	
TOTAL	447	147.27		

xx (P = 0.01)

14. Analysis of variance table for seed quality score

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio
Replicates(R)	3	0.22	0.07	0.44
Cultivars(Cv)	15	40.02	2.67	16.69 xx
Error (a)	45	7.04	0.16	
Whole units	63	47.28		
Plantings(P)	7	21.02	3.00	17.65 xx
P X R	21	3.70	0.18	1.06
P X Cv	105	36.93	0.35	2.06 xx
Error (b)	315	54.54	0.17	
TOTAL	511	163.47		

xx (P = 0.01)

THE END