slower rates in about 8 days after PI, secondary branch primordia started developing on primary branch at the tip. The sequence of development of primary and secondary br primordia gradually progressed downwards. Thus, the development of spikelets also t place in basipetal order. By about 12 days, glumes, lemma and palea were developed these were less developed at the middle of the panicle. At the base, only glumes were fo to be developing. After about 16 days, all the floral parts, except anthers and stigmas, w fully developed at the tip but less developed at the middle. Within 20 days, the ovary fully developed, while the stigmas just started developing. At the middle and the base of panicle, only anthers were developing; stigmas had not yet initiated. By 22 days, all the fl parts were fully developed at the tip, middle and the base of the panicle. Maiti (19 reported that the development of panicle components in the hybrids superceded t parents. The hybrids and their parents have therefore shown distinct patterns in the le of vegetative period and rate of primordia differentiation. The high yielding capabili the hybrids was reflected in their superiority at an early stage of panicle develope Similar studies in other hybrids may validate this conclusion. Rao and Venkateswarlu (19 and Gibson and Schertz (1977) have also shown the superiority of hybrids over their par in terms of panicle development.

Seasonal difference:

The development time of different phenological stages of panicle is short in the ra season, longer in early postrainy season and still longer in late postrainy season in la Hybrid 22E, which was very early maturing, showing considerable deviation from its par in all the seasons. The developmental timetables of CSH1 did not deviate from 22E du the rainy season, but 22E showed much deviation from CSH1 in late postrainy sea However, development of hybrid 22E was early in all seasons when compared to CSH1 (F 5.12-5.13). The hybrids showed considerable decline in growth components in late postr season compared to that in the rainy season (in 1976, India). The dry weight of panic CSH1 and 22E showed steep rise from 36-48 days after panicle initiation beyond which th was no significant increase in growth in rainy season. In late postrainy season, growth of t the cultivars declined considerably but increased again 52 days after PI.

Development and maturity of grain:

The grain is the ripened ovary with attached glumes. During development and matu grains pass through several distinct phases. The process starts with the formation of wa fluid in the grain which is gradually condensed to the milky white stage. This in turn converted to soft, and finally to hard endosperm stage. The grain growth terminates w the formation of black layer at the hilar region. The initiation of black layer shows a sl lunar brownish ring which gradually encircles the hilum and gradually converts it bac a black layer. Phloem parenchyma are blocked with mucilage and pectic compound maturity and form a black layer (Quinby, 1972a).

The structure and ontogeny of the black layer has been studied by Giles *et al.* (19 The early appearance of phenolic compounds in the cells of the phloem parenchym accompanied with the formation of the dark patch adjacent to the transfer cells. mucilage, possibly arising from the breakdown of slime strands, represents slime plug the sieve tubes. The appearance of mucilage coincided with the formation of pectic c pounds and callose indicate the senescence of the phloem tissue and the cessation of ac translocation. The xylem gets separated from the phloem just below the lodicules, and phloem forms a band which continues into the pericarp on the abgerminal side. The cento-chalazal pad lying between the band of phloem parenchyma and the transfer ce made up of thin walled isodiametric cells and is neither crushed or compressed. The bl layer appears as a brown band of tissue near the basal abgerminal side of pericarp in area of transfer cells.

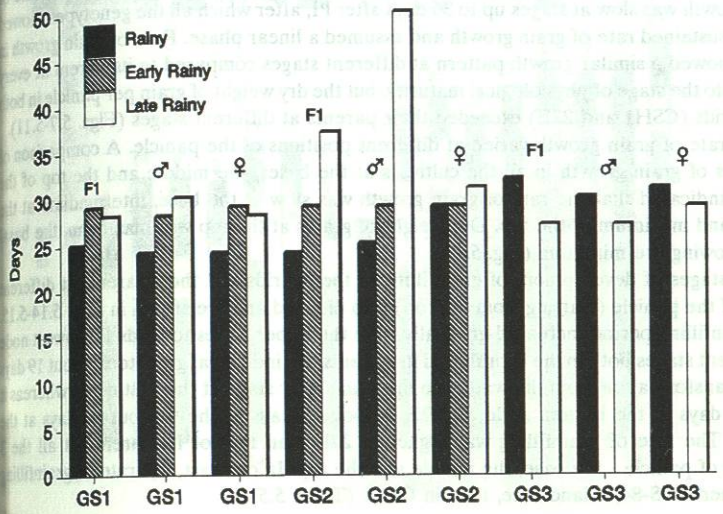

Figure 5.12 Growth stages of hybrd CSH1 and its parents in different growing seasons (Maiti, 1977).

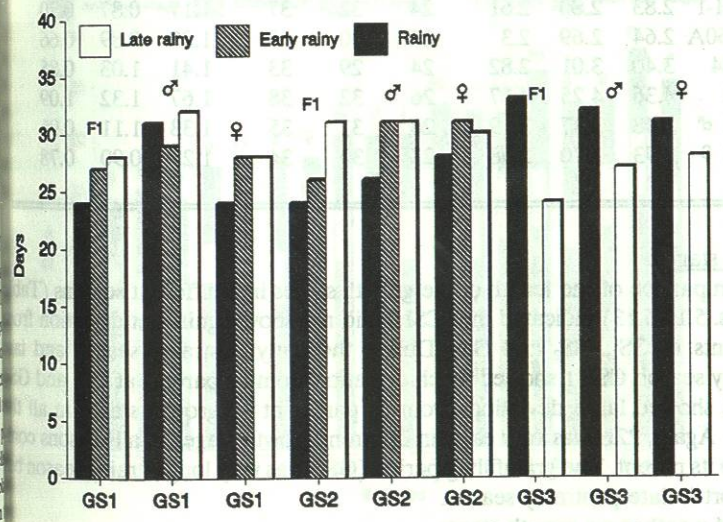

Figure 5.113 Growth stages of hybrd 22E and its parents in different growing seasons (Maiti, 1977).

A comparative study in rainy season on the grain dry matter (on the basis of 100 g weight) at different stages of both CSH1, 22E and their parents indicated that the rate grain growth was slow at stages up to 36 days after PI, after which all the genotypes sho a more sustained rate of grain growth and assumed a linear phase. Rate of grain grow CSH1 showed a similar growth pattern at different stages compared to its parent at e stage upto the stage of physiological maturity, but the dry weight of grain per panicle in the hybrids (CSH1 and 22E) exceeded their parents at different stages (Figs. 5.7-5.1

The rate of grain growth varied at different positions of the panicle. A comparison the rates of grain growth in all the cultivars at the bases, the middle and the top of panicle indicated that the rate of grain growth was slow at the base, intermediate at middle and maximum at the top. Dry weight of grains at the top was maximum, the b grain showing the minimum (Fig. 5.11).

The stages of development of grainfilling in the hybrids and their parents at diffe nodes of the panicle (starting from the top) also differed and are shown in Figs. 5.14 The grainfilling period increased gradually from the upper nodes towards the lowest n at different stages both in the hybrids and its parents. An individual grain took about 19 for its transformation from the watery to the black layer stage at the first node, where took 26 days at the bottom node. In 22E, it took 18 days at the top but 26 days at bottom. The rate of grainfilling was higher in 22E than that of its parents at all th portions of panicle - the base, the middle and the top. In contrast, the rate of grainfi was higher in IS-84, a land race, than in CSH1 (Table 5.5).

Table 5.5 Grain filling period and grain filling rate of CSH-1, 22E an their parents at different locations of panicle (top, middle, base) duri rainy season 1975 (Maiti, 1977).

Genotype	100 seed weight(g)			Grain filling period (days)			Grain filling rate		
	Top	Middle	Base	Top	Middle	Base	Top	Middle	Base
CSH-1	2.83	2.80	2.61	24	32	37	1.17	0.87	0.70
CK60A	2.64	2.69	2.3	22	30	35	1.20	0.89	0.66
IS-84	3.40	3.01	2.82	24	29	33	1.41	1.03	0.85
22E	4.36	4.25	4.17	26	32	38	1.67	1.32	1.09
22E ♂	3.48	3.47	3.19	26	31	35	1.33	1.11	0.91
22E ♀	2.93	2.70	2.68	23	30	34	1.27	0.90	0.78

Growth stages:

A comparison of the length of the growth stages in 4 different seasons (Ta 5.6; Figs. 5.12-5.13) indicated that CSH1 did not show significant deviation fr its parents in GS_1, GS_2 and GS_3. During the early postrainy season and l postrainy season CSH1 showed much deviation from its parents at GS_1 and G but 22E showed large deviations from its parent at all growth stages in all seasons. Again, 22E was very early in different growth stages in all seasons co pared to its parent. The grainfilling period (GS_3) was very long in rainy season very short in late postrainy season.

Effect of weather on growth stage:

Table 5.7 shows the meteorological conditions under 3 stages for the 3 tr

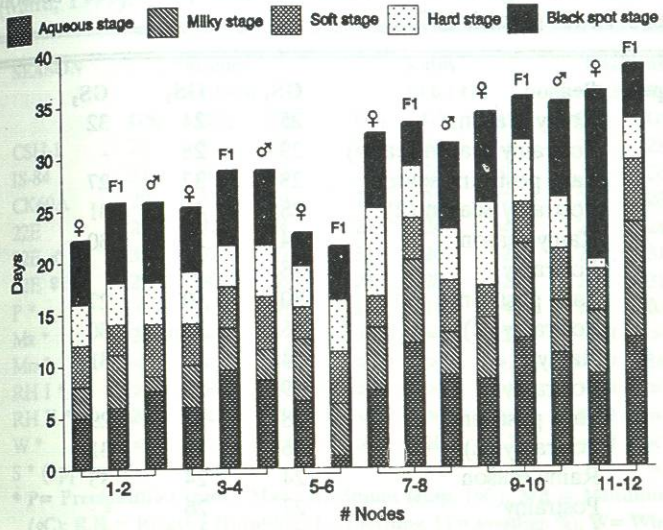

Figure 5.14 Grain filling stage of hybrid CSH1 and its parents in different nodes of the panicle during the rainy season 1975 (Maiti, 1977).

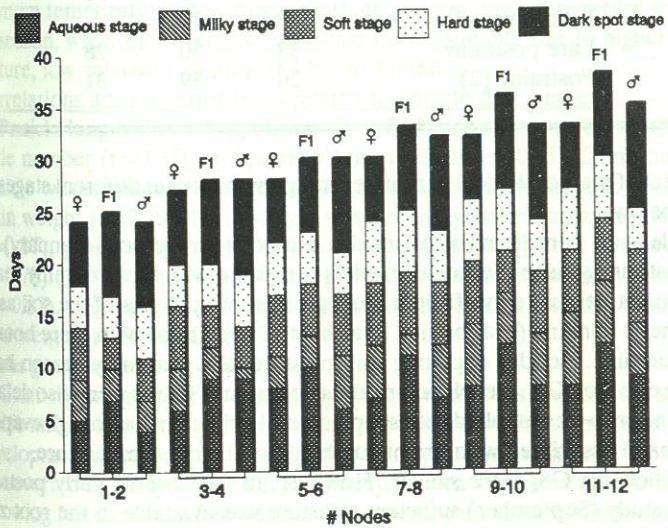

Figure 5.15 Grain filling stage of hybrid 22E and its parents in different nodes of the panicle during the rainy season 1975 (Maiti, 1977).

Table 5.6 Growth stages of CSH1, 22E and their parents in 4 seasons Patancheru, India (Maiti, 1977).

Genotype	Season	GS_1	GS_2	GS_3
CSH1	Rainy season	25	24	32
	Postrainy season (early)	29	28	-
	Late postrainy season	28	37	27
	Postrainy season (2)	28	41	31
IS84 ♂	Rainy season	24	25	30
	Postrainy	28	29	-
	Late postrainy	30	50	27
	Postrainy (2)	35	38	30
CK60A ♀	Rainy	24	28	31
	Postrainy	29	28	-
	Late postrainy	28	31	29
	Postrainy (2)	26	42	31
22E	Rainy season	24	24	33
	Postrainy	27	26	-
	Late postrainy	28	31	-
	Postrainy (2)	24	35	33
22E ♂	Rainy season	31	26	32
	Postrainy	29	31	-
	Late postrainy	32	31	27
	Postrainy (2)	35	35	30
22 E ♀	Rainy	24	28	31
	Postrainy	28	31	-
	Late postrainy	33	30	28
	Postrainy (2)	26	39	31

The effect of meteorological parameters on growth rates at different stages is discussed below:

GS_1: The delay in panicle initiation for the late postrainy seasons (January) as early postrainy season (September) trials compared with those of rainy season (June) might be due to insufficient moisture in the top layers of the soil as the atmospheric demand (evaporation) was high in association with more hours of bright sunshine. Besides depleting soil moisture, the post rainy season had a delaying effect on GS_1. Development and expansion of leaves were also delayed though the crop was supplied with supplemental irrigation due to high evaporative demand associated with bright sunshine and higher temperature.

GS_2: Conditions in GS_2 were similar. However, in the case of early postrainy season's study (September) sufficient moisture was available in the root zone and this ensured that the growth rate was not affected.

GS_3: Fewer hours of bright sunshine and associated low day temperatures were the main causes for the delay in growth rate in the case of rainy season trials

Table 5.7 Weather and growth stages of sorghum in different seasons (Maiti, 1977).

SEASON	Summer 19.1.1976			Rainy 14.6.1975			Post rainy 11.9.1976	
	GS_1	GS_2	GS_3	GS_1	GS_2	GS_3	GS_1	GS_2
CSH-1	29	37	27	25	24	32	29	28
IS-84	31	50	27	24	26	29	28	26
CK60A	29	31	29	24	27	32	29	28
22E	29	31	24	24	24	34	27	26
22E ♂	33	32	29	31	26	32	26	31
22E ♀	29	30	26	24	28	32	28	31
P *	0	0.5	88	142	140	149	21	0.6
Mx *	26-30	>30	>35	>30	=30	25.3	>30	>30
Mn *	<15	<20	=20	>20	>20	>20	>20	16
RH I *	>80	>65	=50	>75	>85	>90	>80	>75
RH II *	20.4	<20	17	<55	>70	>70	>40	=20
W *	<10	<10	<10	>20	10.2	5.2	<10	<10
S * (approx.)		=9			=5			=8

*** P= Precipatition (mm); Mx= Maximum temp. (∝C); Mn = Minimum temp. (∝C); R.H.= Relative Humidity (1= morning, 11= evening; %), W= Wind speed (Km/h), S= Sunshine (hr/day).**

as the moisture was unlimited in this phase. The duration of the grainfilling period appeared to be lengthened by the prevailing lower minimum and maximum temperatures, low bright sunshine and low day temperature in the rainy season, while the reverse was the case during summer due to higher temperature, low relative humidity and bright sunshine.

Correlations among varios traits related to panicle development:

Panicle length showed significant ($P < 0.05$) positive correlation with panicle node number ($r=0.95$), and primary branch length ($r=0.85$). Grain number per panicle was significantly related to the secondary branch number ($r=0.94$), and grain weight ($r=0.79$). Head weight was positively associated with grain number ($r=0.87$), grain weight ($r=0.99$), husk weight ($r=0.83$), and 100 seed weight ($r=0.78$). Days to anthesis showed negative association with primary branch length ($r=-0.87$). GS_3 days were found to show positive association with seed size (100 seed weight; $r=0.85$; Maiti, 1977).

Grain growth pattern (general)

Grain ripening is characterised by grain growth which is associated with increase in size and weight, change in grain color and leaf senescence. The process of grain development starts with the formation of watery fluid in the grain which is gradually converted to milky white, soft and finally hard endosperm stages. Initial growth following fertilization is free nuclear division in the endosperm. Following cell wall formation, the endosperm increases in size (unpublished; see Chapter 2 for details).

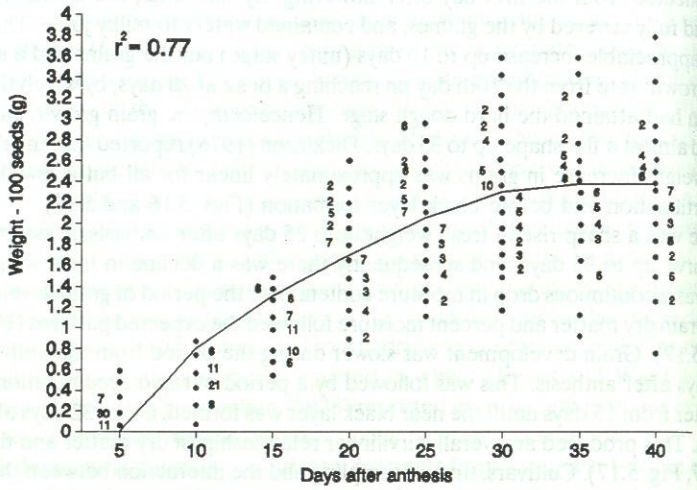

Figure 5.17 Accumulation of dry matter during the grain filling stage of (rainy season; Maiti *et al.*, 1979). (n = 50)

a set of 40 genotypes belonging to different taxonomic groups were chosen (Table 5.8). In order to study their behaviour in different seasons they were grown in early presummer (January) and postrainy season (September), 1976. The development of panicles from the date of initiation to physiological maturity was carefully observed, and the relationship between developmental stages and the yield components were also investigated. The mean number of days required fo each developmental stage and yield components are given in Table 5.9.

Variability in developmental stages:

There was a wide range of variation in the vegetative and reproductive stages among various cultivars. For example, in the January experiment GS_1 ranged from 28 to 39 days, GS_2 from 24 to 64 days and GS_3 from 24 to 29 days. The number of leaves at panicle initiation ranged from 8 to 12, about 6-9 leaves were expanded at panicle initiation. Data on yield components also showed that the cultivars were widely variable. Panicle length ranged from 9.5 to 36.8 cm; node number from 7 to 12.5; number of primary branches from 95 to 71; number of secondary branches from 82 to 409; grains per panicle from 524 to 2307; grain weight per panicle 0.7 to 35 gm; and 100 seeds weight 0.55 to 4 gm. Out of 40 genotypes, only 2 flowered.

A close look at the developmental stages in both the seasons (Table 5.9) indicates that except for the three-leaf stage, all the developmental stages in the vegetative phase were delayed to a greater extent in the January planting than in the postrainy season crop. Stem elongation too was delayed in this season and

Table 5.8 Forty genotypes belonging to different taxonomic groups used in the development study.

Taxonomic group	IS	Origin	Taxonomic group	IS	Origin
Bicolor	714	USA	Durra-Feterita	7089	Equatorial
Bicolor-Kafir	658	USA	Durra-Feterita	7090	Equatorial
Caffrorum	183	USA	Durra-Kafir	3921	USA
Caffrorum-Roxburghii	2210	USA	Durra-Kaura	11025	Ethiopia
Caudatum	9743	Sudan	Durra-Roxburghii	4310	India
Caudatum-Kafir	127	USA	Grass-grains	1059	India
Caudatum-Kaura	7755	Nigeria	Guinese	3819	Africa
Caudatum-Durra	11574	Ethiopia	Margaritiferum	8064	Japan
Caudatum-Guinuese	3460	Sudan	Milo-Kaura	693	USA
Caudatum-Nigricans	8951	Kenya	Nervosum	11085	Ethiopia
Cernum	1054	India		11302	Ethiopia
Conspicuum	3818	Africa	Nervosum Broomcorn		113USA
Conspicuum	7999	Nigeria	Nervosum-Kaoliang	301	USA
Conspicuum	7630	Nigeria	Roxburghii	7276	Nigeria
Dochna-Collier	3648	USA		7818	Nigeria
Dochna-Amber	601	USA		6260	India
Dochna-Honey	633	USA	Roxburghii-Shallu	474	USA
Dochna-Leoti	640	USA	Subglabrescens	11150	Ethiopia
Dochna-Nigricans	2445	USA	Zera-Zera	3541	Sudan
Durra	4850	India			
S.halepense	Bangkok/Tetrapoid		Bangkok		

Table 5.9 Mean estimates of number of days for different developmental stages in 2 seasons (40 genotypes).

Stages	Postrainy season		Late postrainy season	
	Means	SD	Means	SD
1. 3-Leaf stage	4.65	0.48	4.22	1.25
2. 5-Leaf	18.86	1.72	14.41	1.39
3. Panicle initiation	30.68	9.76	30.70	2.56
4. Flag leaf	50.15	9.86	58.11	10.95
5. Boot stage	50.61	10.86	64.85	11.83
6. Half bloom	66.76	10.21	72.22	11.25
7. Soft dough	86.54	6.75	83.44	10.59
8. Hard dough	93.59	8.72	89.11	10.90
9. Physiolog.maturity	100.88	7.17	94.96	10.90
GS_2	36.08	4.92	41.52	11.02
GS_3	34.04	6.46	22.74	2.64

panicle initiation did not show any difference. Stem elongation took longer in January planting but the stages during grainfilling (GS_3, soft dough, hard dough and physiological maturity) were quite early. Seed size was reduced, which may lead to quick filling of the grain. Grainfilling also decreased to half during postrainy season. The components of yield were lower in this season and affected panicle productivity (Table 5.10). This clearly reflected the effect seasonal climate on crop phenology.

Table 5.10 Mean estimates of different yield components during the rainy season and the late postrainy season, 1976 (40 genotypes).

Component	Postrainy SEASON		Late postrainy	
	Means	SD	Means	SD
1. Plant height (cm)	174.88	6.89	-	-
2. Canopy height (cm)	134.26	53.83	-	-
3. Stem elongation (days)	26.93	4.63	34.15	11.44
4. Leaf number	-	-	15.85	2.51
5. Flag leaf area (cm_2)	95.04	7.59	-	-
6. Panicle length (cm)	24.59	13.46	29.41	32.23
7. Panicle dry wt. (g)	32.72	14.79	-	-
8. # secondary branches	-	-	256	85
9. Grain number/panicle	-	-	1100	476
10. Seed wt./panicle (g)	25	16.46	14.80	9.68
11. 100 seed weight (g)	2.67	1.17	1.96	0.79
12. Rate of grain filling per 100 seeds	0.22	1.27	0.09	0.04

The effect of weather on growth stages:

When comparing the differences in the $G6S_1$, GS_2 and GS_3 periods in different taxonomic groups between postrainy and late postrainy seasons, the following conclusions can be drawn (Table 5.11): **1-** on the basis of lifespan, the cultivars may be tentatively divided into 4 groups, A, B, C and D; **2-** in all cases, GS_3 was longer in the late postrainy season; **3-** in group C, GS_2 was longer during the late postrainy season; **4-** in group D, GS_2 was longer during the postrainy season; **5-** the duration of GS_2 increased with high temperature and low realative humidity, bright sunshine hours and clear skies with dry air in the late postrainy season compared to postrainy season; **6-** fifteen genotypes which did not flower in the postrainy season might be sensitive to high temperature and high atmospheric demand. These genotypes might be congenial only for the production of profuse vegetative rather than reproductive growth; **7-** in all cases, GS_3 was shorter in the late postrainy. This might be due to prevail ing high temperature, low relative humidity, longer day length, more hours of bright sunshine, clear skies and dry weather in late postrainy season than in early postrainy season. All these unfavorable atmospheric conditions during late postrainy season might have led to reduction in grain size, quick grainfilling and low grain yield per panicle. Although the panicle size did not decrease in size, grain number and grain weight were much lower. This indicated that the unfavorable weather caused abortion of grains during the late post-rainy season; **8-** it may be assumed that high frequency irrigation was required in late postrainy season to cope with the high atmospheric demands prevailing in that season.

Table 5.11 Crop maturity of different sorghum genotypes in 2 seasons.

Days to maturity	Postrainy season IS No.	Late postrainy season IS No.
80	633	8064
80-90	3951, 3460, 80644 7090, 3851, 3460, 301 9743, 1059, 13	310, 601, 3541, 127
90-100	Bangkok tetraploid, 2210, 183, 4310, 601, 3541, 127, 7090, 474, 301, 474, 9743, 13, 658, 11150, 2445, 3818, 1059, 640, 2210	Bangkok, 183
100-110	3921, 4850,640 658, 11150, 633, 4850, 2445	
110-120	3818	

Crop maturity:

The cultivars showed considerable variation for maturity periods within and between seasons. With a few exceptions, cultivars falling in group A, B and D matured much earlier in the rainy season than in the postrainy season. Cultivars showed shifts in their maturity status in the 2 seasons. A few cultivars (IS 474, IS 3460, IS 9743 and IS 4850) were fairly stable at the maturity stage in both seasons. During the postrainy season, many of the genotypes matured at 90-100 days, but a fairly large number did so between 80-90 days. Although many of the developmental stages were delayed in the late postrainy season, the maturity stage was reached early in many genotypes due to quick grainfilling. All the genotypes falling in group C (except IS 4850. IS 3921) were late in reaching physiological maturity. In other groups, with few exceptions, they matured earlier (Table 5.12).

Relationship among developmental stages (postrainy season 1976):

Some of the developmental stages showed significant correlations among themselves. Stem elongation phase was positively correlated with boot (r=0.44), half bloom (r=0.43) and soft dough (r=0.46). Flag leaf showed a significant negative relationship with panicle initiation (r=-0.56), flag leaf emergence (r=-0.50) and boot stage (r=-0.46). Days to anthesis showed high positive correla

tion with the total number of leaves (r=0.86) and stem elongation (r=0.96). Re
et al. (1984) made a regression approach for prediction of sorghum pheno
(GS_1, GS_2 & GS_3).

Yield components:

A common method of examining the potential of sorghum grain yield is to m
sure the total dry weight and dry grain yield and then compute the harvest in
(HI): Harvest index (HI) = (Dry grain yield) / (Total dry weight)

Dry grain yield = (HI) x (Total dry weight)

A HI of 0.5 or more is an indication of high yields. Of all the components
number of grains per branch is the most important. Panicle size, numbe
primary and secondary branches, grain weight, grain number per panicle
number of heads per unit area could be considered the yield componen
sorghum and understanding their interrelationship is a key to improvemen
sorghum. The degree of relationship among the yield components would deter
the importance of a particular component. Weather conditions, cultural mana
ment and nutrient supply greatly influence yield components. Eastin *et al.* (19
stated that development limitations seems to be critical in grain productio
terms of high temperature stress. Aspects of yield components are discusse
different authors (Kambal and Webster, 1966; Stickler and Pauli, 1961; Blum,
and 1970a; Quinby, 1973; Beil and Atkins, 1967; Fischer and Wilson, 1975b).
effects of temperature on yield components are well documented (Tateno
Ojima, 1976; Chowdhury and Wardlaw, 1978). Grain number per head wa
significantly altered by temperature over the range of temperature (day and n
21/16°C to 26/31°C and 30/25°C to 36/25°C; Chowdhury and Wardlaw, 19
Downes 1972). Yields were markedly reduced at higher temperatures (30/2
35/25°C) due to a reduction in grain weight (Tateno and Ojima, 1976). H
temperatures during panicle development may reduce seed number per head
grain yield (Heinrich, 1981; Ogunlella, 1979).

Castleberry (1973) studied the effect of light energy available per plan
sorghum grain productivity by a series of thinnings. He observed that yield did
decrease until thinnings were done past floral differentiation (FD). Seed nu
per head increased sufficiently to maintain yield until FD, while the plant po
tion was decreased by one-fourth (at about 2 weeds after PI). After this,
could not compensate in terms of seed number per unit of land area and
increase in seed size could not compensate seed number loss (Eastin *et al.*, 19
but Ogunlella (1979) demonstrated that weekly exposure to elevated night te
ratures in the field, 5°C above ambient starting from PI, have reduced yie
seed number per head. Therefore the week after floral differentiation is the
sensitive to elevated night temperature. Dhopte (1984) demonstrated the dele
ous effect of elevated night temperature on microsporogenesis and megaspor
nesis, resulting in poor seed set. González-Hernández (1982) showed dis
temperature and water stress interactions in sorghum.

Eastin *et al.* (1984) stated that sorghum is relatively insensitive to heat
water stress during the vegetative stage, but stress have variable effects du
panicle development, the most sensitive period being about 3 to 6 days after
during microsporogenesis. Stress at post anthesis at 7 to 9 days cause restricti

in seed size and seed number.

Relationship among different panicle components: The number of primary branches showed less positive correlation with panicle length (r=0.46). The number of secondary branches was possitively associated with the number of primary branches (r=0.59). Grain weight per panicle was highly associated with the number of secondary branches (r=0.49) and the number of grains per panicle (r=-0.55; unpublished).

Relationship between growth stages with panicle components: During the summer, the different panicle components like the number of grains per panicle (r=0.51), weight of grains per panicle (r=0.50), 100 seed weight (r=0.51) and number of primary branches (r=0.53) were significantly associated with GS_3 duration ($P<0.01$). Stem elongation was found to be significantly correlated to GS_2 duration (r=0.98). Days to maturity was found to be a function of leaf number, flag leaf, GS_2 and stem elongation ($r^2=0.97$). GS_3 duration was a function of number of secondary branches, number of grains per panicle and grain wieght per panicle ($r^2=0.36$). Grain number was found to be linearly correlated with the number of secondary branches ($Y = 17+0.13X$, $r^2=0.51$). Grain number was found to be a function of secondary branches, primary branches, GS_3 and grain weight ($r^2=0.58$). Grain size (100 seed weight) was a function of the rate of grain filling ($Y = 0.28+19.1X$, $r^2=0.89$). Grain weight showed relationship to secondary branches, grain number per panicle, primary branches and GS_3 ($r^2=0.39$). It was again found to be correlated to duration of grainfilling (r=0.50). Therefore, the rate of grainfill and duration of effective grainfill were both correlated with panicle productivity. Grain number and effective grainfilling period were not correlated with days to anthesis, which suggests that these characteristics were independent of maturity. Days to maturity was found to be a function of flag leaf stage, leaf number, GS_2 and stem elongation ($r^2=0.93$; unpublished).

GENERAL COMMENTS

The transformation of the vegetative apex to the reproductive apex is the most important phenomenon in the life cycle of cereals. Temperature and photoperiod are the 2 important factors controlling this internal autonomous progression, when crops are grown under optimum soil moisture and nutrient conditions. This change in the formation of a completely dissimilar structure is a hormone controlled phenomenon and guided by photothermal interactions prevailing in the growing season of the crop. This phase represents the cessation by 1 group of genes and the initiation of activity by another (Milthrope and Moorby, 1976).

Most sorghum genotypes seem to be short day plants and on the basis of their response to day length, they can be grouped into photoperiod-insensitive, obligate photoperiod-sensitive, and facultative photoperiod-sensitive. Photothermal interactions play an important role in controlling flowering of these 3 groups. For this reason, temperate sorghum behave differently when grown under tropical environments. To break this tropical-temperate barrier, a suitable crossing program should be adopted in order to develop cultivars for broad adaptations.

This approach could give greater impetus to the sorghum crop improve
program. In the tropics, photosensitive sorghum grows very tall in the rainy sea
and often produces a large number of leaves and a few productive heads. To av
this, photoinsensitive sorghum are generally preferred.

As yield is the primary goal of the breeder, optimum growing conditions
essential for the expression of a crop's full genetic potential. Significant yi
improvement has been achieved in different crops, but only under high in
situations. In these favorable environments, the potential yield is determi
during the early stage of inflorescence development and the panicle meriste
capable of producing the optimum number of florets to their full genetic poten
This is simultaneously substantiated by the optimum photosynthetic efficiency
leaf attained during the vegetative stage. Nevertheless, it is very difficult to pro
congenial growing conditions in most semiarid regions of the world. Often, cr
are prevented from expressing their full genetic potential. The productivity
panicle is drastically reduced due to several unfavorable environmental conditi
like lack of water, low nutrients availabillity, salinity, high temperature,
Therefore, major research efforts need to be directed to screen genotypes wh
could express their optimal genetic potential under unfavorable field conditio

In substantiation of this, under water stress situations, the growth and devel
ment of panicles is affected to an extent by the intensity of water stress at differ
stages of development. Under severe water stress when cell division is of pa
mount importance, spikelet differentiation tends to stop but under moderate str
situation, differentiation may be delayed not suspended. Under severe water str
failure of stem and internode elongation leads to poor or no exertion of t
panicle. There could be a drastic reduction in floret nunmber, thereby impair
the final productivity of the panicle and crop. Water stress affects the germinat
of pollen and growth of pollen tubes on stigmas. During grain development, wa
stress affects the sustained growth rate of grain. This ultimatedly leads to p
seed setting and filling of the grain and drastic reduction in seed size. It also h
a direct effect on seedling establishment (Chapter-3). Therefore, drought avo
ance trait with its capability to complete panicle development and anthesis wit
a short span of time is an adaptive mechanism. Lines could be selected from t
group which express better panicle growth. These could be incorporated in t
crop improvement program.

A full understanding of the reproductive apex and its interaction with envir
ments could provide some clues for the selection of cultivars and genetic impro
ment of the crop.

The maximum yield is determined by the potential of a crop variety and
adaptation to a particular environment. At present, breeders look for a dwarf pl
with a compact panicle. However, in a tropical environment, compact pani
provides a favorable environment for the infestation and disease, like grain mo
and earhead bugs. A lax panicle provides less opportunity for the developm
of the biotic stress. The focus of research should be to increase grain number
panicle and grain weight rather than evolving a dwarf plant prone to infestati
An ideotype in sorghum needs to be formulated for better adaptation in
environment.

6

ROOT DEVELOPMENT AND GROWTH

INTRODUCTION

Physiologists are more interested in the above ground portions of plants which play the central role during photosynthesis in plant metabolism. Very little attention is given to studies on the growth and function of root systems. This is partly due to the unavailability of an efficient technique for the extraction of roots from the field. Considerable variation in the expression of the size of roots occurs under different environmental conditions (Russell, 1977). Due to the difficulties involved, most research endeavors concerning root studies are conducted in greenhouses, growth chambers, rhizotrons and a few are based on observations in the field (Kaigama *et al.*, 1977). It is not possible to make a complete analysis of the growth and function of either roots or shoots unless the interrelationship between them and their behaviour in edaphic systems is taken into account (Russell, 1977).

Different techniques have been adopted to study root development in different crops. In sorghum, soil cores are taken from the field with the help of tubes to study depthwise distribution of roots and to correlate the relationship between root and the above-ground portion of the plant at different morphological development stages. Root mophogenesis and early growth have been done mostly in hydrophonic culture (Blum *et al.*, 1977 a,b), sand culture (Nour and Weibel, 1978), and glass house pot culture (Hacket, 1973). Böhm (1977) described and compared different methods of root observation, both destructive and nondestructive in a natural environment in mini-rhizotrons. The use of clear tubes buried in the soil, or mini-rhizotron, has been described by different authors (Waddington, 1971; Böhm, 1977). Böhm (1977) stated that mini-rhizotrons required less time for data collections compared to other methods. Other methods have been adopted for the study of root system in different crops (Newmann, 1966; Marsh, 1971; Tennant, 1975; Voorhees, 1976; Sanders and Brown, 1978; Foale and Upchurch, 1982).

An endoscope introduced into a transparent tube and placed into the soil before sowing has been used for direct observation of root distribution and intensity of root colonization (Martens and Clauzel, 1982).

The root system of sorghum plants grown in soil measured at 9, 14 and 17 days from sowing indicate the low average diameter of the root number and the very high extension rate. Sorghum appeared to maintain a stable relationship between the overall number, length, surface area and volume of its root (Hackett, 1973). In sorghum, both under irrigated and non-irrigated conditions a rapid penetration