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STUDIES ON GROWTH AND DEVELOPMENT OF PANICLES AND GRAINS OF SOME SORGHUM HYBRIDS AND THEIR PARENTS

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Summary

Comparative studies were made on growth and development of panicles, flowering behaviour and maturing of grains of CSH—1, 22E and their parents, from its transformation from vegetative meristem to floral meristem in three seasons, Kharif, Rabi and Late Rabi. The sequence of some recognizable growth stages during GS2 GS3 have been noted. It has been observed that during Kharif season, CSH-1 does not deviate much from its parents although in some characters it has shown some expression of good growth but in most characters 22E has shown higher degree of heterosis compared to its parents. The growth curves of CSH-1 and 22E have shown that 22E was fast growing in major characters but panicle length in CSH-1 in major stages was higher than that of 22E. CSH-1 has not shown much deviation from its parents in the developmental time tables of panicle and flowering behaviour during Kharif but has shown much deviation from its parents during late Rabi, whereas 22E has shown much deviation from its parents both during Kharif and late Rabi. Grain filling periods in different nodes at subsequent stages have shown that the hybrids CSH-1 and 22E have taken longer time from the respective parents during Kharif but during late Rabi CSH-1 is almost similar to its parents. On the other hand 22E is earlier compared to its parents. Rate of grain filling in 22E is always higher compared to its parents. Number of grains formed and their dry weight at all stages are higher in the hybrids compared to its parents. This study indicates that meteorological parameters in different seasons play a great role in the flowering behaviour and maturity of grains.

Introduction

To understand the physiological basis of crop growth and yield in sorghum, a more thorough understanding of plant processes and functions is needed. Developmental processes should be thoroughly studied before determining the effect of physiological process in these developmental aspects[1].

The physiological aspects of growth and yield have been studied to some details in wheat and barley by different workers[2,3].

Eastin[4] has made a critical review about our present status of knowledge regarding control of panicle initiation and flowering. Maturity differences amongst sorghum varieties are supposed to be due to differences in responses of photoperiod and temperature[5,6] Doggett[7] has made a review of the literature regarding factors controlling panicle initiation and flowering. The influence of planting date on bloom and length of grain filling period has been studied by Pauli *et al*[8]. Studies on hybrids and parents for PI, bloom and physiological maturity indicate that the time required to reach PI or complete GSI was less for hybrids than their respective parents, but hybrids took more days in expandig the panicles and longer grain filling period than their parents[9] Dalton[10] has shown that significant correlation exists between GS3 days and yield under favourable conditions. The possibility of selection for GS3 days has been emphasized for genetic improvement of yield in sorghum[4] Seed number and seed size components are impor tant factors in sorghum. yield analysis.[4] Developmental morpho logy of the sorghum kernel has been studied by differ ent workers.[11-12]

The development of panicles of sorghum has been studied at Nebraska by Lee *et al.*[13] Vanderlip has described in detail the developmental and physi ological growth phases of sorghum but very little is known about the time sequence of morphological changes during the growth of the panicle and its components from the panicle initiation to physiological maturity. Infor mation is also lacking on the rate of growth of different parts of the panicle and on the grain filling period of individual grains at different locations in the panicle.

The Nebraska group of scientists has described the growth stages of sorghum, e.g., (1) GS1 from the date of sowing to the onset of the reproductive phase (panicle initiation); (2) GS2—from the panicle initiation to flowering; (3) GS3—flowering to physiological maturity (black layer formation). In GS1, six to nine leaves are in expanded condition, followed by the expansion of the remaining leaf initial. In GS2, the internodes are expanding and simultaneously the remaining additional leaves are also expanding. GS2 is the critical stage at which seed number is established.[14]

The object of the present study is (1) to follow in detail the growth and development of the panicle in two hybrids and their parents from the stage of floral initiation to physiological maturity; (2) to make further partitioning of GS2 and GS3 phases on the basis of the morphological appearance of the crop and to record the time sequences of the recognizable morphological changes. The study was carried out in three different seasons—Kharif (June-Aug.), Rabi—dry winter (Sep.-Nov.), Late Rabi or early summer (January-March).

Materials and Methods

Coordinated Sorghum Hybrid 1 (CSH-1) and its parents—IS84 (male), CK60A (female); and Pioneer hybrid 22E and its parents—R22E (male), A22E (female) were grown in two replications in 75 cm rows with plot size of 18m^2 during the Kharif season 1975 (14 June in black soil). The same has been repeated in late Rabi or early summer (19 January 1976, in red soil). The experiments were conducted at ICRISAT Site, Patancheru (17.2° N, 545 m).

For studying the detailed flowering behaviour and maturity of grains, the six genotypes were also grown in the experimental garden during early Rabi 1976 (11 September) in small plots.

Regular sampling of panicles was carried out at intervals of four days from the date of panicle initiation to the physiological maturity for growth analysis. In addition, ten plants in each replication were tagged and the stages of physiological phases, flowering sequences and grain filling period were noted. Development of grain and grain growth was also studied.

For the sake of convenience, the different recognizable growth stages are described below:

(1) Panicle initiation—the stage when the vegetative meristem is transformed to the floral meristem (corresponding to stage 3 of Vanderlip—growing point differentiation), (2) flag leaf emergence (stage 4—Vanderlip)—the emergence of the flag leaf blade. This is the last leaf initiated at the end of the vegetative phas; (3) boot stage (stage 5): (a) boot emergence—showing the tip of the boot; (b) half leaf and full boot condition—at this stage the head is fully developed and is enclosed by the flag leaf sheath; (4) panicle emergence—the emergence of the panicle from the flag leaf sheath; (5) full panicle —the panicle has completely emerged from the flag leaf sheath; (6) flowering —the emergence of anthers beginning at the tip of the panicle and proceeding downwards. Thus 25%, 50% and 100% flowering stages can be recognized by the progress of the emergence anthers down the length of panicle (50% flowering corresponds to half bloom—stage 6 of Vanderlip); (7) seed set (visible grains)—visible grains formed along the entire length of the panicle starting from the tip of the panicle; (8) watery stage—grains containing watery fluid; (9) milky stage—watery fluid condensed to milky juice; (10) hard stage (soft dough to hard dough stage)—milky juice is gradually condensed to hard stage (soft dough—stage 7; hard dough—stage 8); (11) black layer—formation of black layer at the hilum region indicating the termination of the vascular connection and food supply to the grain. 50% black layer indicates the progress of black layer up to the middle of the panicle and 100% up to the full panicle.

Besides the above parameters, the following quantitative characters were measured at intervals of four days from the date of the initiation of panicle primordium:

A. Vegetative phase—stem length and internode length were measured because the growth of these parameters is predominant starting from the date of panicle initiation.
B. Reproductive phase—length of panicle, number of nodes on the rachis, number of primary branches, number of secondary branches, number of visible grains formed, dry weight of panicle, dry weight of grains per panicle and 100 seed weight.

Observations and Discussion

Panicle development (GS2-GS3): The growth pattern of the panicle and the panicle components in Kharif are shown graphically. In CSH-1 characters like number of primary branches, number of secondary branches, are of mid parent level but heterosis is evident in terms of stem length (Fig. 1) and internode length

(Fig. 2). Amongst CHS-1 and its parents the growth curve of stem stands between the two parents up to 32 days after panicle initiation (PI), beyond which

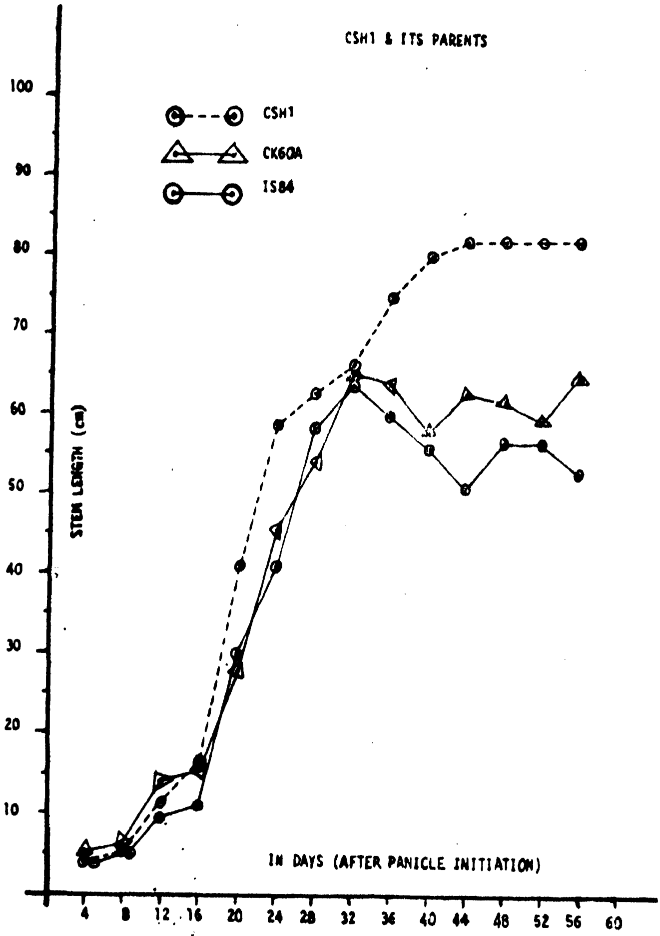


Fig. 1. Growth pattern of stem length in CSH1 & its parents at different stages (Kharif—1975)

the hybrid vigour is expressed; whereas there is negligible growth in both the parents (Fig. 1). Though the growth of the panicle in CSH-1 does not exceed its parents at earlier stages, at later stages after 36 days (after PI), it has exceeded its parents (Fig. 3). The dry weight of panicle in CSH-1 has exceeded that of its parents at all stages (Fig. 4). The number of secondary branches have exceeded its parents at all stages (Table 1).

22E has shown higher degree of heterosis over its parents in most of the characters like internode length, stem length, panicle length, dry weight of panicle (Figs. 5-8) and number of primary branches (Table 1).

TABLE 1—Number of primary and secondary branches at different stages in CSH-1, 22E and their parents (Kharif 1975)

Genotype	Days after panicle initiation						
	32	36	40	44	48	52	harvest
CSH-1							
No. of PB/panicle	45.16	48.00	48.55	48.87	49.75	56.78	56.20
No. of SB/panicle	215.14	240.00	264.91	267.86	262.82	284.77	280.00
IS-84							
No. of PB/panicle	36.18	47.37	48.70	48.95	49.23	48.86	49.05
No. of SB/panicle	210.14	218.19	234.00	239.55	259.87	267.70	289.95
CK60A							
No. of PB/panicle	38.95	49.73	49.40	49.95	49.50	54.25	62.20
No. of SB/panicle	198.33	227.00	240.70	245.60	244.89	254 00	260.20
22E							
No. of PB/panicle	40.13	50.42	50.52	53.50	53 00	56.25	55.15
No. of SB/panicle	154.60	194.90	230.00	220.30	212.44	233.88	262.55
Male 22E							
No. of PB/panicle	35.14	41.05	44 70	45.53	44.50	44.75	48.05
No. of SB/panicle	179.54	210.55	203.85	200.86	200.19	204 15	213 85
Female 22E							
No. of PB/panicle	38.14	50.00	51.13	53.50	51.25	54 75	53 05
No. of SB/panicle	195.60	241.63	256.20	263.00	252.61	261.50	281.65

PB—Primary branches
SB—Secondary branches

When compared with CSH-1, it was observed that 22E is fast growing in major characters like stem length and internode length (Table 1), but in 22E, the growth of panicle length has exceeded CSH-1 in major stages (Figs. 5-8). Number of secondary branches are higher in CSH-1 compared to 22E at different stages (Table 1).

In all cases in both the hybrids and their parents, the growth of internode, stem length, panicle length and panicle dry weight do not show appreciable increase up to 16 days (after panicle initiation) beyond which there are steep rises of growth reaching the peak at 32-36 days (after PI). Henceforth, there is no significant increase in growth (Figs. 5-8).

Seasonal difference: Growth components of panicle at different stages of growth of CSH-1, 22E and their parents in two seasons, Kharif and late Rabi, are given in the Tables 1 & 2. It is evident from the results that the growth of panicle and its components have declined considerably in January planting. To have a comparative outlook, the growth components of panicle in CSH-1 and 22E in Kharif and late Rabi are represented in the graphs

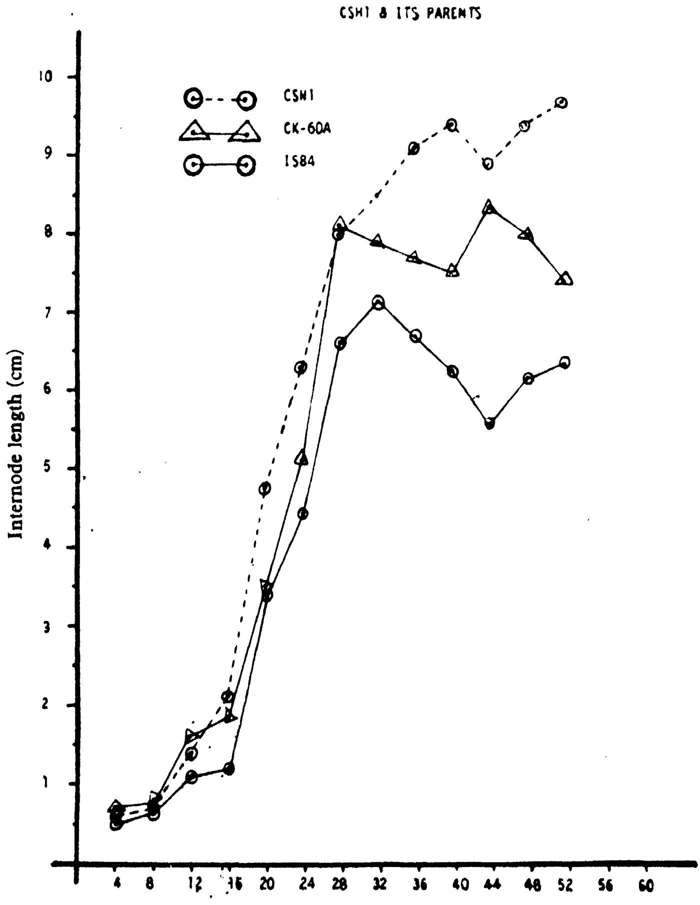


Fig. 2. Growth pattern of inter node length in CSH1 and its parents at different stages (Kharif-1975)

(Fig. 9). It shows that CSH-1 and 22E have declined considerably in the growth of panicle length, panicle dry weight, number of primary and secondary branches at different stages in the late Rabi compared to that in the

TABLE 2—Panicle components of CHS-1, 22E and their parents (Kharif and Late Rabi)

		Days after panicle initiation											
		32		36		40		44		48		52		Final Stage	
		Kh	LR	Kh	LR	Kh	LR	Kh	LR	Kh	LR	Kh	LR	Kh	LR
Panicle length (cm)	CH-1	25.74	17.42	25.12	18.09	27.57	22.53	28.92	23.56	30.30	30.84	29.40	25.74	29.85	25.87
	IS84	25.85	1.03	25.37	1:14	30.17	2.71	28.97	15.31	32.45	22.30	28.27	19.21	30.36	21.82
	CK60A	24.23	16.63	22.12	18.42	23.45	18.91	22.92	18.48	23.87	18.34	23.65	18.60	23.76	18.20
Dry weight of panicle (g)	CSH-1	4.40	0.38	7.16	2.62	20.62	3.51	38.30	3.88	44.45	5.07	58.31	13.67	79.96	46.59
	IS84	3.94	—	5.16	0.03	14.09	0.40	24.13	1.39	37.82	4.47	40.67	5.39	42.18	33.73
	CK60A	3.00	0.78	4.78	2.86	15.57	2.44	25.15	3.34	42.91	4.57	47.69	4.99	50.21	13.33
Number of grains/ panicle	CSH-1	859.95	594.50	1325.29	517.00	1370.95	708.63	1470.74	946.38	1491.50	973.25	1716.43	882.82	1819.70	1297.54
	IS84	756.25	—	874.42	—	1015.65	—	1025.25	653.63	1172.50	597.92	1184.00	698.50	1112.25	963.85
	CK60A	715.14	269.00	824.25	458.38	1032.62	672.12	1070.50	701.25	1173.50	647.00	1320.75	925.63	1395.10	852.45
Dry weight of grains/ panicle (g)	CSH-1	—	—	5.48	—	13.17	—	21.02	—	138.30	—	50.39	—	57.88	—
	IS84	—	—	3.59	—	8.00	—	16.62	—	28.82	—	32.40	—	28.29	—
	CK60A	—	—	3.30	—	9.39	—	15.90	—	30.56	—	36.07	—	38.12	—
Panicle length (cm)	22E	22.78	16.81	22.70	17.26	24.30	18.56	23.05	19.75	24.30	20.10	25.65	20.55	24.98	21.65
	Male 22E	22.05	10.92	19.00	11.54	20.87	11.87	19.50	18.30	22.05	21.01	22.27	18.87	22.16	19.10
	Female 22E	20.75	16.04	23.04	15.22	24.40	19.24	22.30	19.08	24.77	16.20	24.12	18.00	24.45	—
Dry weight of panicle (g)	22E	4.18	0.43	6.74	2.69	18.07	4.23	28.21	7.72	62.00	7.27	66.00	12.79	71.58	36.27
	Male 22E	1.12	0.35	5.53	4.07	10.86	4.68	15.03	5.18	30.44	9.92	48.06	10.02	59.71	43.63
	Female 22E	1.78	0.45	6.47	1.86	14.83	1.74	24.95	2.40	32.66	2.61	40.29	3.38	50.87	—
Number of Grains/ panicle	22E	825.53	244.25	1017.87	436.63	1068.25	567.88	1133.50	683.25	1241.75	729.25	1356.25	725.75	1536.98	989.45
	Male 22E	525.34	397.17	660.50	606.25	1016.87	657.85	997.50	723.20	1122.50	731.63	1100.25	671.25	1163.65	919.35
	Female 22E	615.13	315.63	818.12	437.88	1017.75	396.38	965.75	497.63	1243.00	493.88	1211.00	631.98	1228.10	—
Dry weight of grains/ panicle (g)	22E	—	—	5.23	—	11.00	—	20.80	—	43.80	—	51.40	—	51.36	—
	Male 22E	—	—	4.15	—	3.13	—	9.13	—	20.80	—	31.98	—	40.88	—
	Female 22E	—	—	4.72	—	8.23	—	17.94	—	23.04	—	31.56	—	35.83	—

Kharif season. The dry weight of panicle in CSH-1 and 22E has shown steep rise from 36 days onwards to 48 days (after PI) beyond which there is no significant increase in the growth curve in Kharif but in late Rabi the growth curve of both the genotypes have declined considerably which again shows sudden rise only at 52 days (after PI) (Fig. 9).

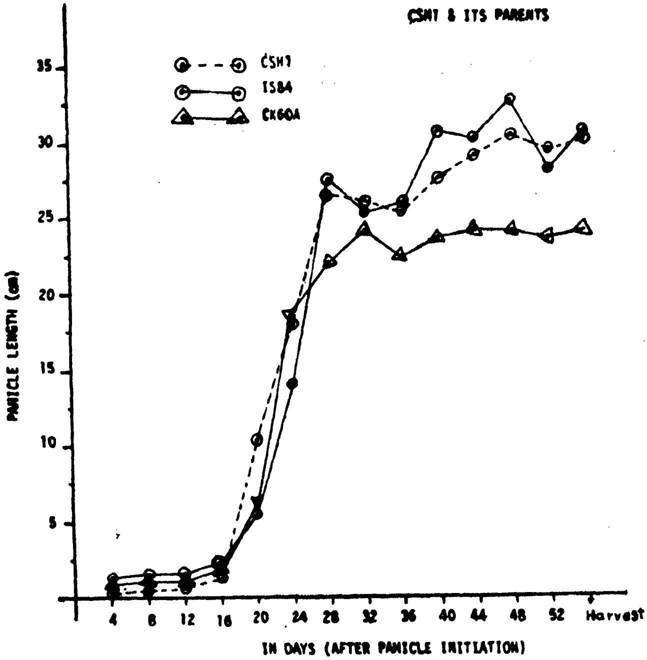


Fig. 3. Growth pattern of panicle in CSH-1 and its parents at different stages (Kharif—1975)

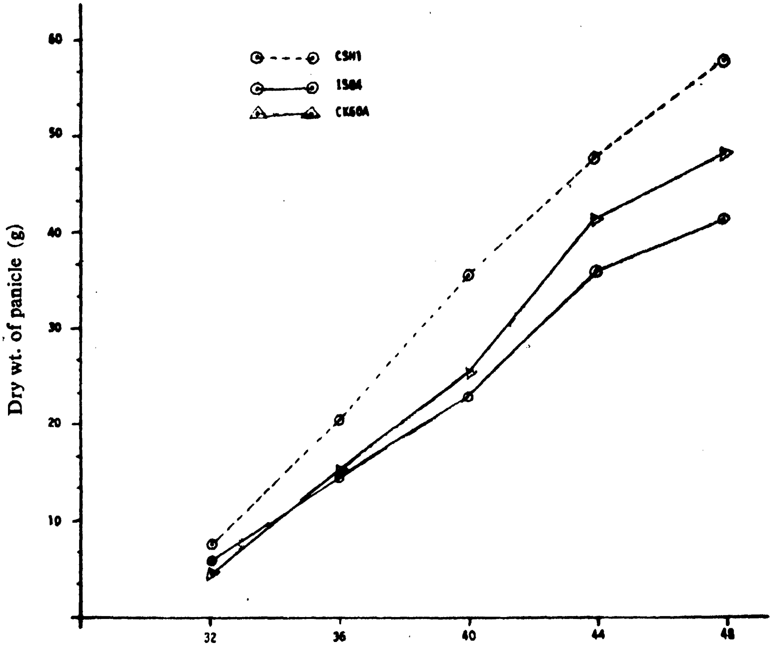
Developmental time tables: Development of panicle components: At panicle initiation, there is a sudden elongation of the vegetative shoot apex with a construction at the base. Later on, the panicle meristem initiates the primary branch primordia basipetally, which in turn produce secondary branch primordia and ultimately spikelets. By that time all the leaf initials have been formed. The developmental time tables of the components of panicle and floral parts (samples collected at different intervals) are given in tabular form (Table 3).

It is observed that CK60A (female parent) is earlier in the development of primary branch primordia, secondary branch primordia and floral parts compared to that in the hybrid CSH-1 and the male parent—IS84, but 22E is earlier than its male and female parents.

TABLE 3—Developmental time tables of panicle components at different locations of panicle meristem

Days after PI	CSH-1	IS84	CK60A	22E	Male 22E	Female 22E
4	Bulbous primary branch primordia initiated	Primary branch primordia initiated and developing	Primary branches already developed. Secondary primordia developing	Primary branches well developed. Secondary branch primordia initiated and developing	Primary branches developing and secondary branch primordia initiating	Primary branches developed and secondary primordia initiated and developing
7	Secondary branch primordium developing at the tip of panicle	Top—secondary branch primordia developing; base—secondary primordia initiating	Primary and secondary branches prolonged; glumes developing	Glumes initiating	Secondary branch primordia not fully developed	Top—secondary branch primordia developing; and middle & base—developing
11	Top—glumes, lemma & palea well developed; middle glumes well developed, lemma, palea not so developed; base—glumes developing	Top—spikelets developing and glumes initiated	Top & middle-glumes well developed; base-developing	Top & middle—lemma and palea developed; base—developing	Top—lemma & palea developing; middle & base—lemma & palea initiating	Top—lemma & palea initiated and developing; middle & base—not initiated
15	Top—all the floral parts developed but the anthers not initiated; middle & base—floral parts not fully developed & anthers not initiated	Top—lemma & palea well developed; middle—less developed; base—lemma & palea developing	Glumes, lemma & palea well developed, anthers not initiated	Top & middle—Androecium and Gynoecium well developed: base—developing	Top & middle Anthers initiated; base—not initiated	Anthers not initiated, lemma, palea well developed
19	Top—ovary developed; stigma initiated & developing; middle & base—anthers developed but stigma not initiated	Top & middle—anthers developed; base—anthers not initiated	Top—anthers developed, stigma initiated & developing middle—stigma initiating; base—anthers initiated and developing	—do—	Top & middle—Androecium & Gynoecium developed base—Androecium developed & Gynoecium developing	Top—anthers initiated and stigma initiating; middle & base—anthers initiating
22	Top, middle & base—all parts well developed	Gynoecium developed throughout the panicle	All parts well developed	—do—	—do—	Anthers & stigma developed; others top, middle & base developing

Recognizable morphological stages of panicle: CSH-1 and its parents: In Kharif, panicle initiation starts 25 days after emergence in CSH-1, one day later than its parents. Both CSH-1 and its parents take 13 days after panicle



In days (after panicle initiation)

Fig. 4. Growth pattern of panicle dry wt. in CSH-1 and its parents at different stages (Kharif—1975)

initiation to reach the flag leaf stage and 39 days to reach the boot emergence stage. Within 3 days, the full boot has emerged in CSH-1. Panicle emergence in CSH-1 takes about 43 days after emergence of seedling and 28 days after panicle initiation but its female parent (CK60A) shows slight deviation (45 days). Anther emergence starts at 49 days after emergence in CSH-1 and IS84; and at 52 days in CK60A (Table 4).

Seasonal difference: The developmental time tables of the panicle is lengthened in early Rabi (September) and still more in late Rabi (e.g., for panicle emergence, CSH-1 takes 43 days in Kharif, 51 days in early Rabi and 62 days in late Rabi). During Kharif CSH-1 has not shown much deviation from its parents but in late Rabi it shows much deviation from 22E and its parents. In Kharif panicle initiation starts at 24 days after emergence in 22E and its female parent but 31 days in its male parent. For flag leaf emergence it takes only 38 days in 22E and its female parent, but 45 days in male parent. It

TABLE 4—Developmental time tables of panicles of CSH—1, 22E and their parents in different seasons
(Kharif, early Rabi and late Rabi)

		Days after emergence of seedlings										
Genotype	Seasons	Panicle initiation	Flag leaf emergence	Boot initiation	Boot stage	Panicle emergence	Top flowering	50% flowering	100% flowering	Top black layer	50% black layer	Complete black layer
CSH-1	Kharif	25	38	39	42	43	49	50	52	73	81	86
	Rabi	29	45	46	50	51	57	59	60	—	—	—
	Late Rabi	28	55	58	61	62	65	67	68	87	92	97
IS84	Kharif	24	38	39	42	43	49	50	52	73	79	83
	Rabi	28	45	46	50	51	57	59	60	—	—	—
	Late Rabi	30	64	68	73	77	80	81	83	102	107	111
CK60A	Kharif	24	38	39	43	45	52	53	54	74	82	88
	Rabi	29	44	45	51	53	57	59	61	—	—	—
	Late Rabi	28	45	48	53	55	59	60	62	85	88	90
22E	Kharif	24	38	39	42	43	48	42	51	74	81	85
	Rabi	27	42	43	47	48	53	55	57	—	—	—
	Late Rabi	28	48	51	55	57	59	60	62	80	83	87
Male 22E	Kharif	31	45	46	51	52	57	58	59	82	89	93
	Rabi	29	51	52	55	57	60	62	63	—	—	—
	Late Rabi	32	55	58	61	62	63	64	66	84	90	94
Female 22E	Kharif	24	38	39	42	43	52	53	54	75	83	87
	Rabi	28	46	47	51	53	59	62	62	—	—	—
	Late Rabi	28	45	48	53	55	58	59	61	82	86	90

takes 14 days for the developing panicle of 22E and its female parent to reach to the flag leaf stage but it takes 15 days for the male parent.

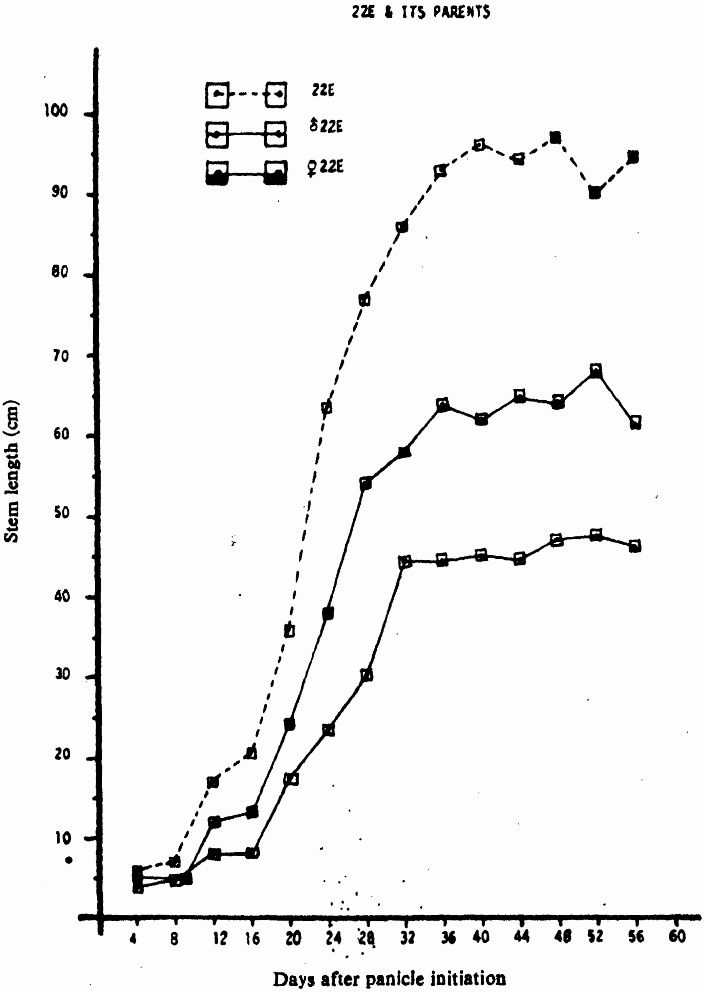


Fig. 5. Growth pattern of stem length in 22E and its parents at different stages (Kharif—1975)

The comparative time tables of panicle development during Kharif indicates 22E is much earlier than male 22E in all phases and than female 22E at later phases of panicle development (for 50% flowering 22E—42 days; female 22E —53 days).

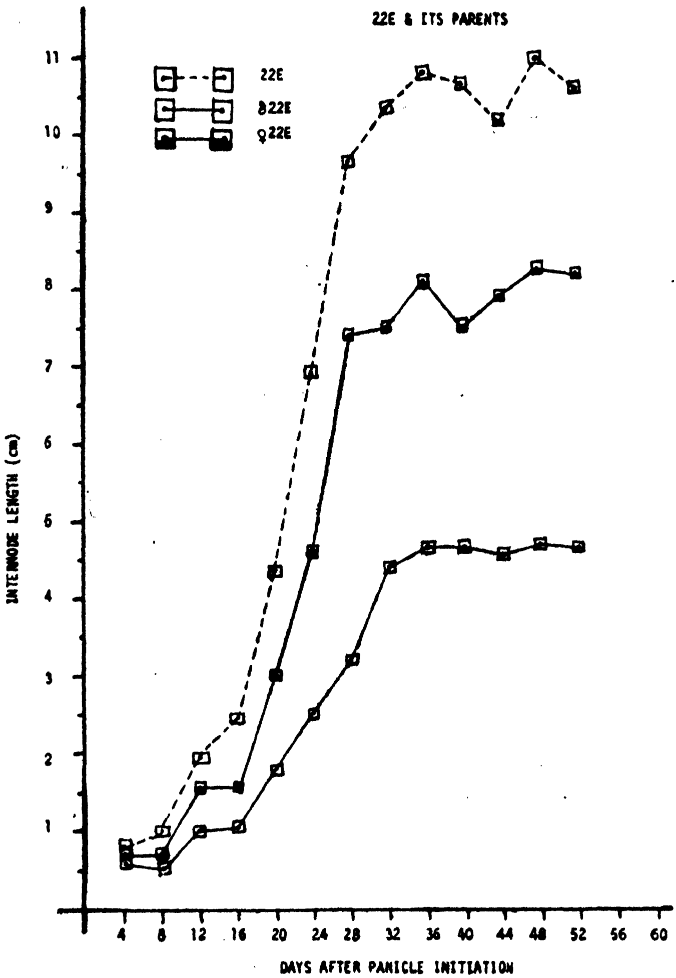
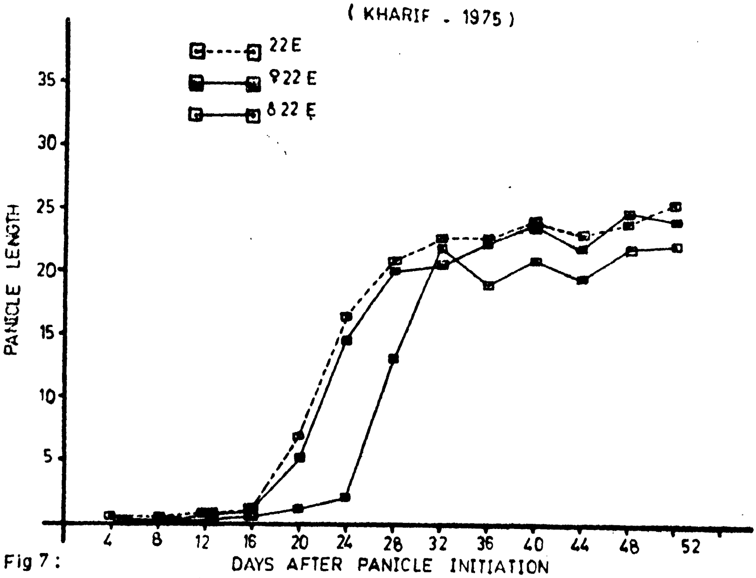


Fig. 6. Growth pattern of internode length of 22E and its parents at different stages (Kharif—1975)

Seasonal difference: The developmental time tables are long in Rabi and still more in late Rabi; for example, 22E takes 38 days for the flag leaf emergence in Kharif, 42 days in early Rabi and 48 days in late Rabi (January).



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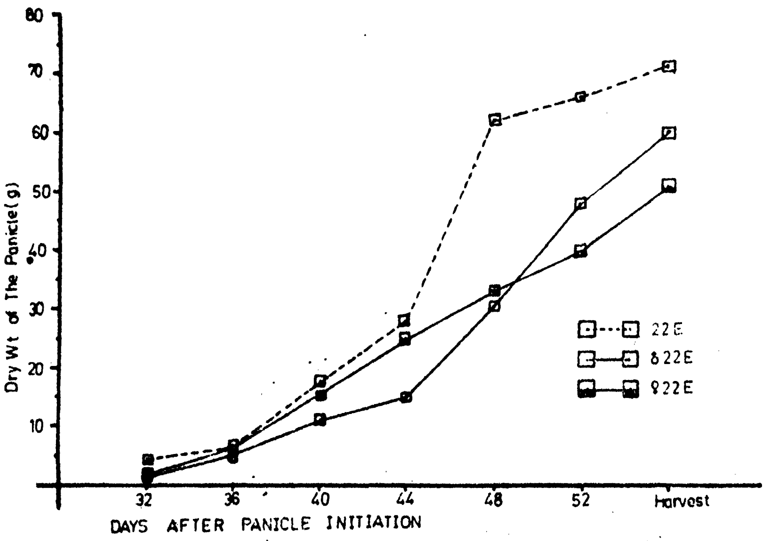


Fig. 8. Growth pattern of panicle dry wt. in 22E and its parents at different stages (Kharif—1975)

22E which is very early, has shown much deviations from its parents in all the seasons.

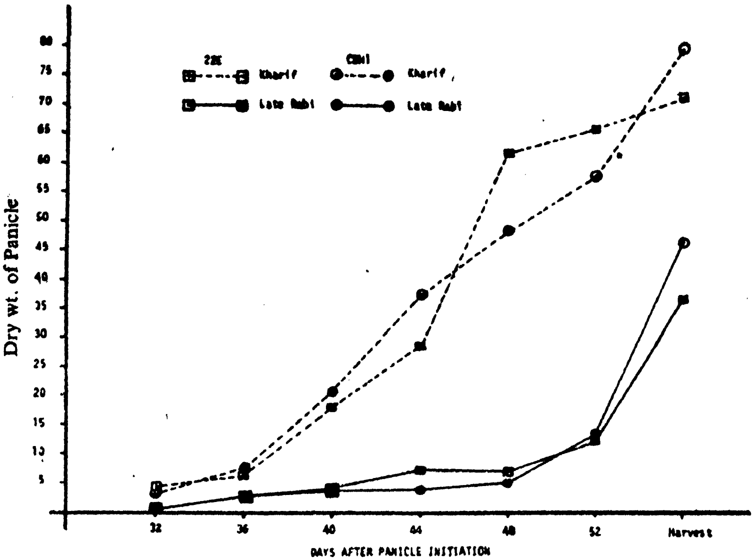


Fig. 9. Growth pattern of panicle dry wt. in CSH-1 and 22E at different seasons (Kharif—1975)

The developmental time tables of CSH-1 does not deviate from 22E during Kharif but 22E shows much deviation from CSH-1 in late Rabi. 22E is very early in all the seasons compared to CSH-1.

Grain growth (*GS3*): The development and maturity of the grains pass through several recognizable phases. The process starts with the formation of watery fluid (liquid endosperm) in the grain, which is gradually condensed to milky white stage. This is converted to soft and finally hard endosperm stages. The initiation of black layer shows a semi-lunar brownish ring which gradually encircles the hilum and the entire hilar tissue of the grain is ultimately converted to a black layer. This region is somewhat depressed.

The phloem parenchyma cells are blocked with mucilage and pectic compounds at maturity causing the black layer.[15] Quinby[16] interpreted black layer formation as indicator of physiological maturity. Initial black layer correlates well with maximum dry weight[17].

Grain number: As the development and maturity of grains are basipetal, the number of visible grains will gradually increase with ages. Although the grains are actually set at pollination, the number of grains visible at different stages may give us an idea aboût the degree of grains set. The grains are counted after separating the glume and later on are dried.

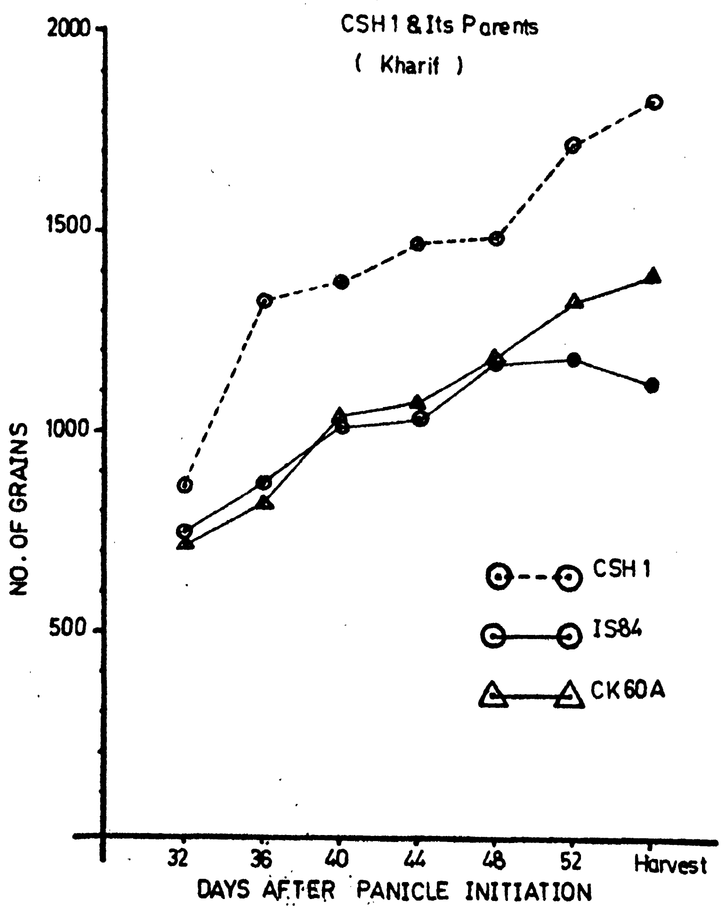
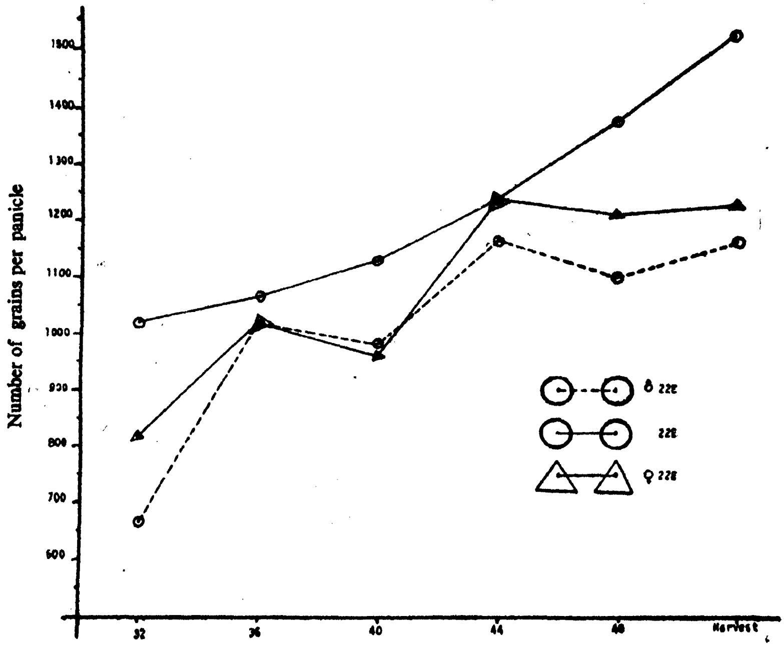


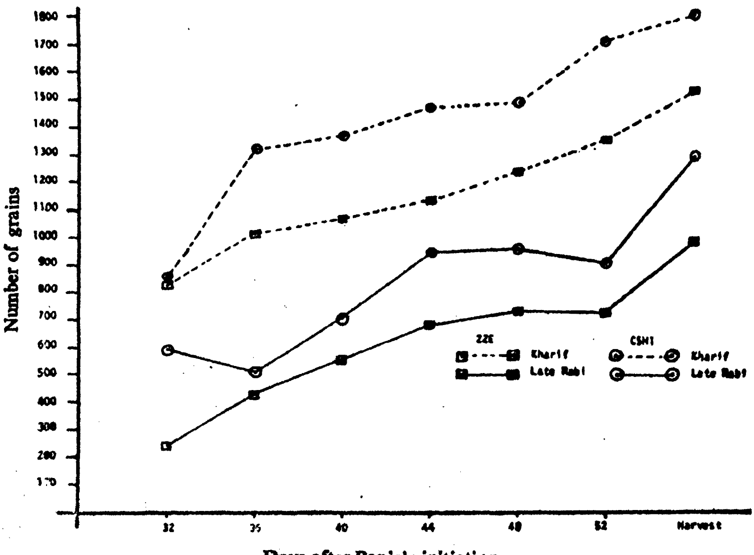
Fig. 10. Growth Pattern of Grain no (Visible) in CSH-1 and its parents at different stages (Kharif—1975)

It is indicated that the number of grains in CSH-1 shows sudden rise from 32 days to 36 days after PI after which the rate of growth of grain number is slow, which becomes more or less stable from 44 days onwards (Fig. 10), but 22E has shown higher growth rate of grain number at all stages up to the



Days After panicle initiation

Fig. 11. Growth pattern of grain set (Visible) in 22E and its parents at different stages (Kharif—1975)



Days after Panicle initiation

Fig. 12. Growth pattern of grain Set (Visible) of 22E and CSH 1 at different seasons (Kharif—1975)

physiological maturity (Fig. 11). From 44 days onwards (after PI) there is again a sharp rise in grain number in both the hybrids.

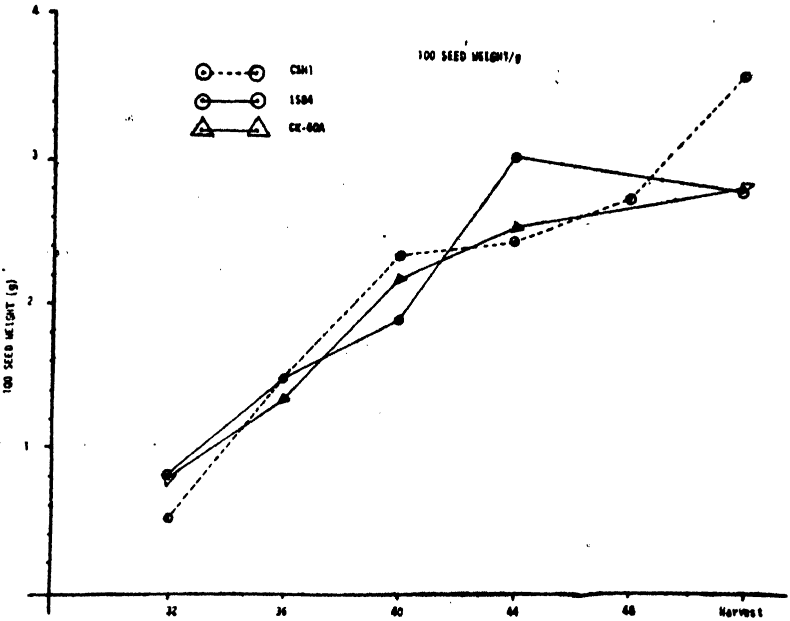
Seasonal difference: A comparative study on the number of grains set at different stages in CSH-1 and 22E indicates that both during Kharif and late Rabi the number of grains set at each stage has exceeded the grain number of 22E, thus showing the high yielding capability of this hybrid (Fig. 12), The rate of grain setting is much declined in late Rabi in both the hybrids (CSH-1 and 22E) (at 40 days after panicle initiation, the number of grains per panicle in CSH 1—Kharif 1371, late Rabi 709; 22E—Kharif 1068, late Rabi 568).

Dry matter accumulation in grains (Kharif): A comparative study in Kharif on the grain dry matter (on the basis of dry weight of 100 seeds) at different stages of both CSH-1, 22E and their parents (Table 5) indicates that the rate

TABLE 5—100 seed weight (g) at base, middle and top of the panicle at different stages (Kharif 1975)

Genotype	Stage	Days after panicle initiation				
		32	36	40	44	48
CSH-1	Base	0.42	1.44	2.03	2.10	2.61
	Middle	0.48	1.34	2.46	2.50	2.80
	Top	0.65	1.68	2.60	2.73	2.83
IS84	Base	0.60	1.09	1.44	2.82	—
	Middle	0.78	1.43	1.96	3.01	—
	Top	1.06	1.92	2.35	3.20	—
CK60A	Base	0.65	1.20	2.04	2.32	—
	Middle	0.75	1.32	2.18	2.69	—
	Top	0.98	1.51	2.34	2.64	—
22E	Base	0.65	1.57	2.68	3.46	4.17
	Middle	0.82	1.86	3.07	3.64	4.24
	Top	0.93	2.38	3.36	4.05	0.36
Male 22E	Base	0.36	0.77	1.20	2.42	3.19
	Middle	0.48	0.97	1.40	2:86	3.47
	Top	0.59	1.77	1.87	3.18	3.48
Female 22E	Base	0.59	1.31	2.01	2.77	2.68
	Middle	0.70	1.48	2.03	2.86	2.70
	Top	0.91	1.70	2.25	2.84	2.93

of grain growth in all genotypes is slow at earlier stages up to 36 days after PI, after which all the genotypes show a higher, more sustained rate of grain growth. The rate of grain growth in CSH-1 shows in general a mid parent value at different stages up to 48 days after which it has exceeded its parents (Fig. 13), 22E in contrast shows much faster rate of grain growth compared to its parents at every stage up to the stage of physiological maturity (Fig. 14). The dry weight of grains per panicle in both the hybrids (CSH-1 and 22E) has exceeded their parents at different stages (Fig. 15 & 16).



Days After Panicle Initiation

Fig. 13. Growth pattern of grain dry wt. (100 seed wt.) in CSH 1 and its parents at different stages (Kharif—1975)

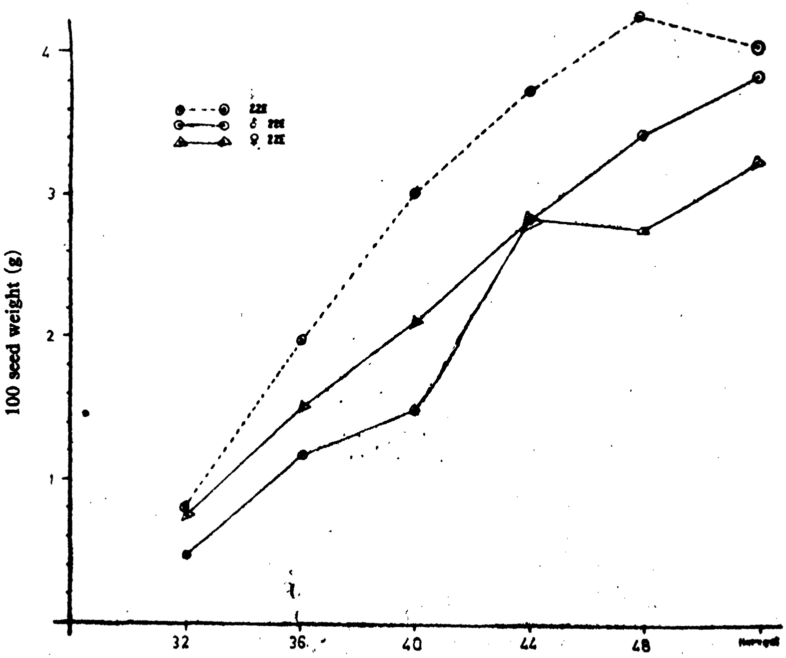
A comparison of the rate of grain growth (D.M) in all the genotypes at bases, middle and top of the panicle indicates that the rate of grain growth is always slower at base, intermediate at middle and maximum at the tip (Fig. 17). Dry weight of grains at the tip is maximum, the basal grain showing the minimum,

The dry weight accumulation of grains in 22E at all locations (base, middle and top) and at all stages are much higher than that of CSH-1 (Fig. 17).

Grain Filling: Measurements of the grain filling period during the Kharif in different nodes indicates that the hybrids CSH-1 and 22E take a longer time than their respective parents to reach the black layer stage (22E—34 days; male 22E—31 days; female 22E—30 days; CSH-1—31 days; IS84—24 days and CK60A—30 days (Table 6). The stages of development of grain filling in CSH-1 and its parents at different nodes of the panicle (starting from the top) are shown in Figure 18 and 22E and its parents in Figure 19.

TABLE 6—Growth stages of CSH—1, 22E and their parents in three seasons

Genotype	Season	GS1	GS2	GS3
CSH—1	Kharif	25	24	32
	Rabi	29	28	—
	Late Rabi	28	37	27
IS84	Kharif	24	25	30
	Rabi	28	29	—
	Late Rabi	30	50	27
CK60A	Kharif	24	28	31
	Rabi	29	28	—
	Late Rabi	28	31	29
22E	Kharif	24	24	33
	Rabi	27	26	—
	Late Rabi	28	31	24
Male 22E	Kharif	31	26	32
	Rabi	29	31	—
	Late Rabi	32	31	27
Female 22E	Kharif	24	28	31
	Rabi	28	31	—
	Late Rabi	28	30	28



In days (After Paincle initiation)
Fig. 14. Growth pattern of grains dry wt. (100 seed wt.) in 22E and its Parents at different stages (Kharif—1975)

The grain filling period increases gradually from the upper nodes towards the lowest node at different stages both in hybrids and its parents (Fig, 20 & 21). An individual grain takes about 19 days for its transformation from the

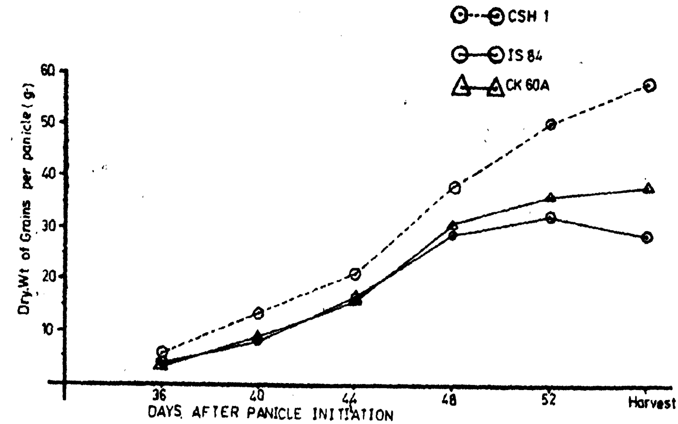


Fig. 15. Growth pattern of Dry. Wt accumulation in grains per panicle of CSH 1 and its parents at different stages (Kharif—1975)

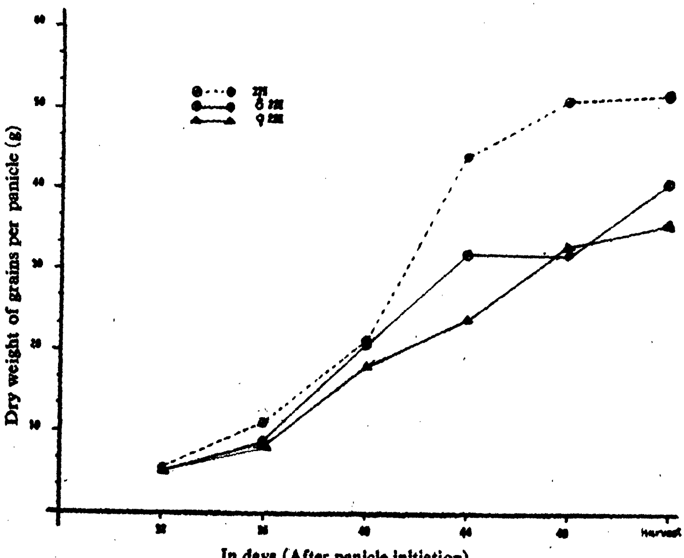


Fig. 16. Growth pattern of Dry weight accumulation in grains per panicle of 22E and its Parents at different stages (Kharif—1975)

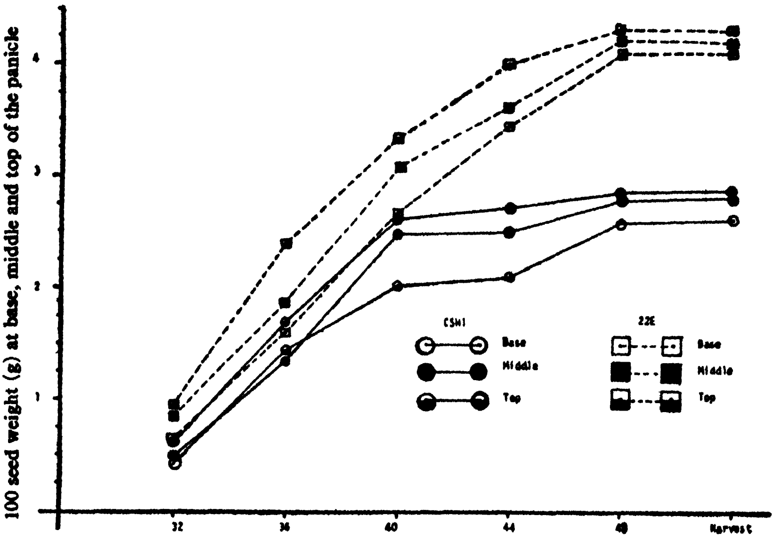


Fig. 17. Growth pattern of grain Dry wt. (100 seed wt.) at base, middle and top of the panicle (22E and CSH 1) at different stages (Kharif—1975)

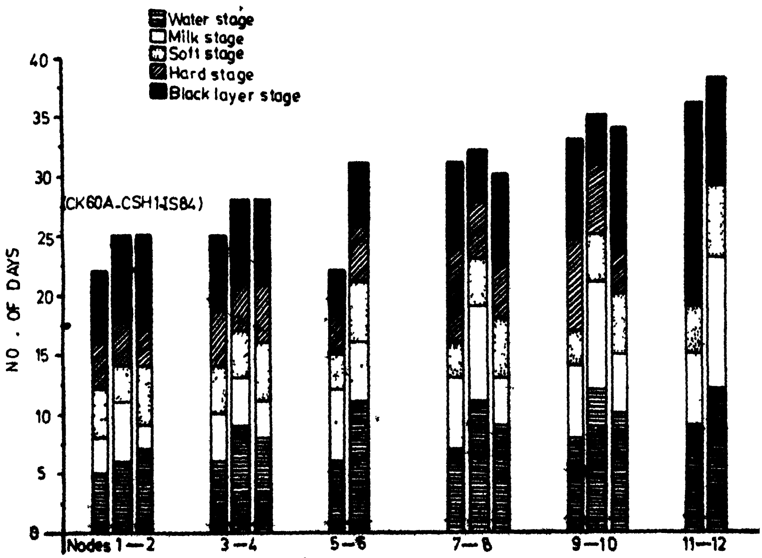


Fig. 18. Stages of Development of Grain Filling in CSH 1 and its parents at different nodes of the panicle (Kharif—1975)

watery to the black layer stage at the first node (the top of the panicle) whereas it takes 26 days at the bottom node; in 22E it takes 18 days at the top but 26 days at the bottom. For complete black layer, it takes 13 days from the top to bottom in CSH-1 and 22E. Rate of grain filling is higher in

TABLE 7—Grain filling period and grain filling rate of CSH—1, 22E and their parents at different locations of panicle (top, middle, base) during Kharif 1975

Sl. No.	Genotype	100 seed weight (g)			Grain filling period (days)			Grain filling rate (mg)		
		Top	Middle	Base	Top	Middle	Base	Top	Middle	Base
1.	CSH—1	2.83	2.80	2.61	24	32	37	1.17	0.87	0.70
2.	CK60A	2.64	2.69	2.32	22	30	35	1.20	0.89	0.66
3.	IS84	3.40	3.01	2.82	24	29	33	1.41	1.03	0.85
4.	22E	4.36	4.25	4.17	26	32	38	1.67	1.32	1.09
5.	Male 22E	3.48	3.47	3.19	26	31	35	1.33	1.11	0.91
6.	Female 22E	2.93	2.70	2.68	23	30	34	1.27	0.90	0.78

22E than that of its parents at base, middle and top of thc panicle. In contrast, the rate of grain filling is higher in IS84 and CK60A than that of CSH-1 (Table 7; Figs. 20 &21).

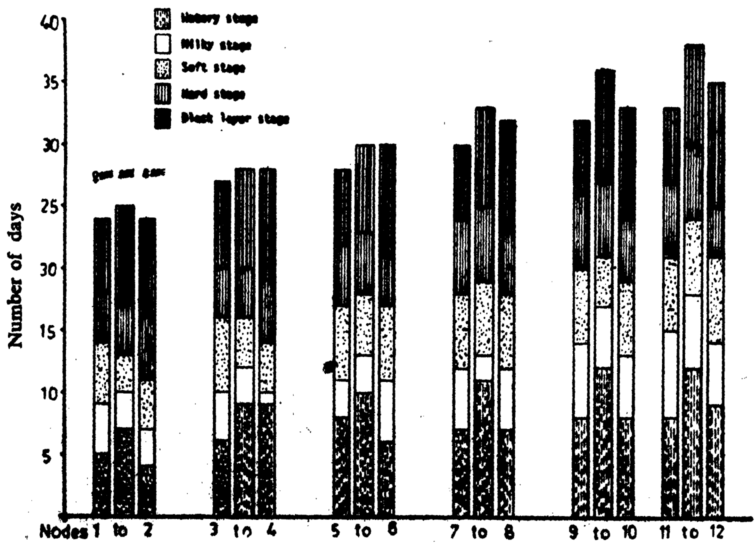


Fig. 19. Stages of development of grain filligs in 22E and its parents at different nodes of the panicle

Heterosis: Both the hybrids CSH-1 and 22E have shown heterosis at different stages (calculated on the basis of percentage increase over the mid parent and better parent value) in various characters like DM of panicle, number of grains set and dry weight of 100 seeds, but the degree of heterosis is much higher in 22E (Fig. 23) compared to that in CSH-1 (Fig. 22).

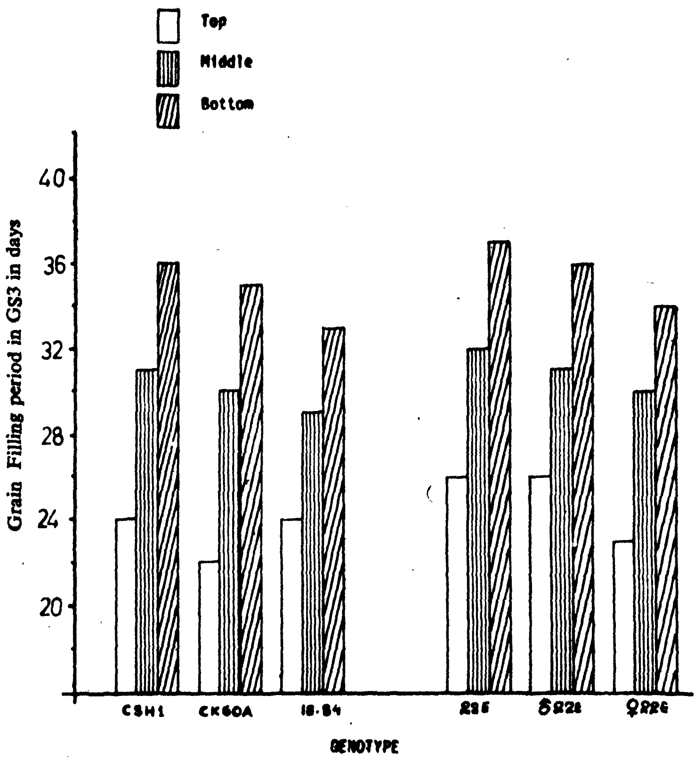


Fig. 20. Grain filling period in CSH 1 and 22E and their parents at Base, middle and top of the panicle. (Kharif—1975)

The degree of heterosis percentage is less in different characters in late Rabi (January) in both the hybrids (CSH-1 and 22E) (Table 8); for example, in 22E at 32 days after panicle initiation, the heterosis percentage (over better parent) in panicle dry weight is 235 in Kharif but only 123 in late Rabi.

Growth stage: A comparsion of the length of the growth stages in three seasons (Table 6; Figs. 24 and 25) reveals the following facts :

In Kharif CSH-1 does not show significant deviation from its parents in GS1 (CSH-1-25 days; IS84-28 days; CK60A-28 days); in GS2 (CSH-1-24 days;

TABLE 8. Heterosis % (over better parent and mid parent value)

Hybrid	Characters	Seasons	Parents	Days after panicle initiation 32	36	40	44	48	52	Final Stage
22E	Dry weight of panicle (g)	Kharif	BP	234.83	104.17	121.85	113.06	189.83	163.81	140.71
			MP	288.27	112.33	140.62	141.12	196.51	149.39	129 46
		Late Rabi	BP	122.86	66.09	90.38	149.03	73.29	127.64	83.13
			MP	107.50	91.50	131.78	203.69	115.95	190.89	83.13
	Number of grains/panicle	Kharif	BP	134.20	124.42	104.96	117.37	99.89	111.99	125.15
			MP	144.77	137.12	105.01	115.47	104.99	117.36	128.52
		Late Rabi	BP	61.49	72.02	86.32	94.48	99.67	108.11	107.62
			MP	68.53	83.63	107.73	111.93	119.01	111.38	107.62
	100 seed weight (g)	Kharif	BP	104.62	109.58	129.53	144.98	131.56	153.43	124.06
			MP	130.77	133.33	145.11	169.27	131.56	137.99	128 89
CSH-1	Dry weight of panicle (g)	Kharif	BP	76.14	149.79	132.43	152.29	115.24	122.27	159.25
			MP	71.94	144.06	139.04	155.44	122.49	131.98	173.11
		Late Rabi	BP	48.72	91.61	143.85	116.17	110.94	273.95	349.51
			MP							
	Number of grains/panicle	Kharif	BP	120.25	160.79	132.76	137.39	127.09	129.96	130.43
			MP	116.89	156.04	133.86	140.35	127.15	137.05	145.15
		Late Rabi	BP	221.00	112.79	105.43	134.96	150.43	95.38	152.21
			MP							
	100 seed weight (g)	Kharif	BP	68.75	64.56	110.45	108.26	95.69	—	126 50
			MP	69.84	63.75	104.96	115.12	87.77	—	126.95

BP — Better parent ; MP — Mid parent

IS84-25 days; CK60A-28 days) and GS3 (CSH-1-32 days; IS84-30 days; CK60A-31 days), but during early Rabi and late Rabi CSH-1 shows much deviation from its parents in GS1 and GS2 (GS2 in CSH-1, Kharif-25 days early Rabi-28 day, late Rabi-37 days, IS84-25-29-30 days, CK60A-28-28-31).

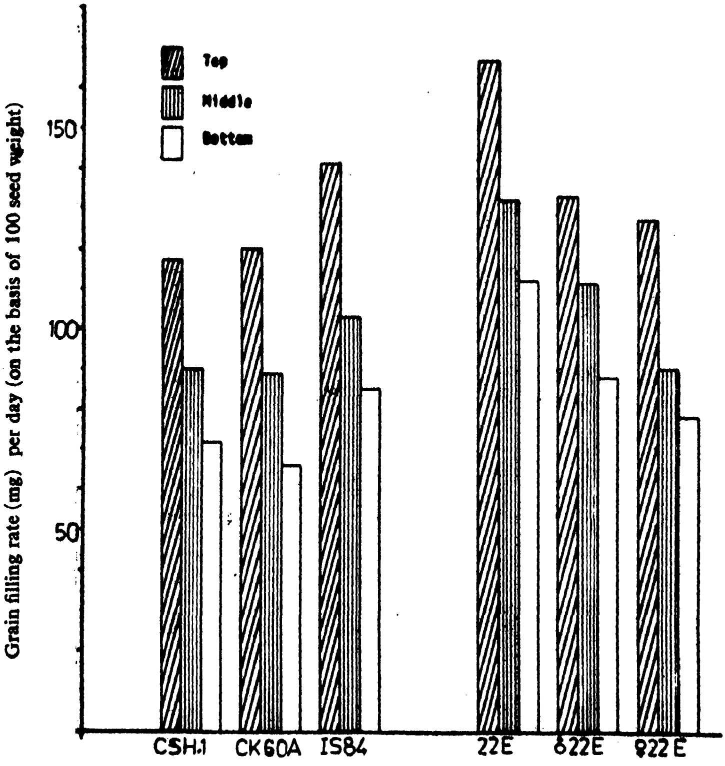


Fig. 21. Grain filling rate in CSH 1 and 22E and their parents at base, middle and top of the panicle (Kharif—1975)

22E shows many deviations from its parents in all growth stages in all the seasons (GS2-22E: Kharif-24 days, early Rabi-26 days, late Rabi-31 days, male 22E-26-31-31 days, female 22E-28-31-30).

22E is very early in different growth stages almost in all seasons compared to its parents. The grain filling period (GS3) is very long in Kharif but very short in late Rabi (Figs. 25 and 26).

The effect of weather on growth stage : Table 9 shows the meteorological conditions under the three stages for the three trials. The effect of meteorological parameters on growth rate at different stages are presented below:

(1) GS1 phase: The delay in growth rate for the late Rabi (19-1-1976) and early Rabi (11-9-1976) trials compared to Kharif (14-6-1975) trial is mainly due

TABLE 9—Weather and growth stages of sorghum in different seasons

	Summer			Kharif			Rabi		
	19.1.1976			14.6.1675			11.9.1676		
	GS1	GS2	GS3	GS1	GS2	GS3	GS1	GS2	GS3
CSH−1	29	37	27	25	24	32	29	28	
IS84	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	
Male 22E	33	32	29	31	26	32	26	31	
Female 22E	29	30	26	24	28	32	28	31	
P	00	0.5	87.7	141.5	148.8	139.8	20.7	0.6	
M_X	26-30	>30	>35	>30	=30	25-30	>30	>30	
M_N	<15	<20	=20	>20	>20	>20	>20	16·20	
R.H.I	>80	>65	=50	>75	>85	>90	>80	>75	
R.A.II	20·40	<20	17	>55	>70	>70	>40	=20	
W	<10	<10	<10	>20	10-18	5-15	<10	<10	
S		= 9			= 5			= 8	

P=Precipitation mm; M_X=Maximum temperature °C. M_N=Minimum temperature °C; R.H.=Relative humidity (I=Morning, II=Evening) %, W=Windspeed, kmph; S=Sunshine hours/day

to insufficient moisture in the top few cms of the soil as the atmospheric demand (evaporation) is high in association with more hours of bright sunshine. Even though the temperatures are low in January trial, this cannot be attributed as a cause, because in September trial this is not fulfilled.

(2) GS2 phase: Same as above. However, in the case of September trial sufficient moisture is available in the root zone, by which the growth rate has not affected much.

(3) GS3 phase: Low hours of bright sunshine and associated low day temperatures are the main causes for the delay in the growth rate in the case of Kharif (14-6-1975) trial compared to the other trials as the moisture is unlimited in this phase.

Table of means for different variables of panicle component and growth stages are given in Table 10.

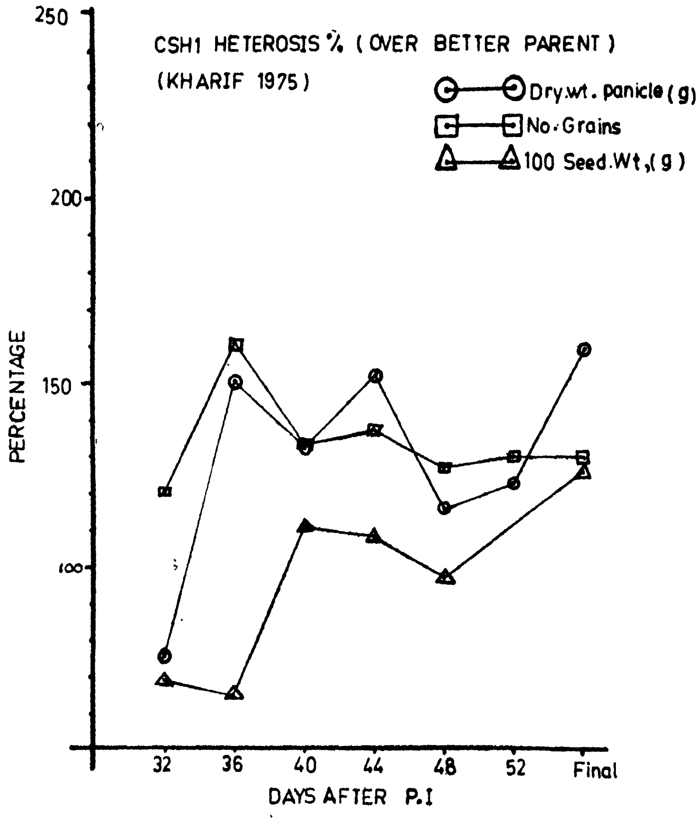


TABLE 10. Table of means for different variables

Variable	Mean	S.D.	Maximum	Minimum	Range
1. Panicle length (cm)	23.75	8.39	53	9.55	43 45
2. Node number	8.62	2.61	12.5	2.00	10.5
3. Primary branch number	48.07	13.24	71.01	19.50	51.51
4. Length of primary branch (cm)	7.13	7.03	41.19	3.16	38.03
5. Number of secondary branches	264.63	85.59	409 65	82.63	327 02
6. Grain number	1115.42	470.58	2307.5	292.5	2015
7. Head weight. (g)	15.26	9.53	43.64	0.78	42.86
8. 100 seed weigh (g)	1.96	0.79	4.08	0.55	3.53
9. Days for anthesis	40.38	10.17	66	28	38
10. GS 1	30.19	1.88	36	28	8
11. GS 2	37.58	10.15	64	24	40
12. GS 3	25.12	2.34	31	20	11

Panicle length is positively correlated with node number (r=.95**), primary branch length (r=.85**) at 1% level. Number of secondary branches is positively associated with grain number per panicle (r=.94**), grain weight (r=.79*). Head weight is positively correlated with grain number (r=.87**), grain weight (r=.99), husk weigh (r=.83), 100 seed weight (r=.78*). Days to

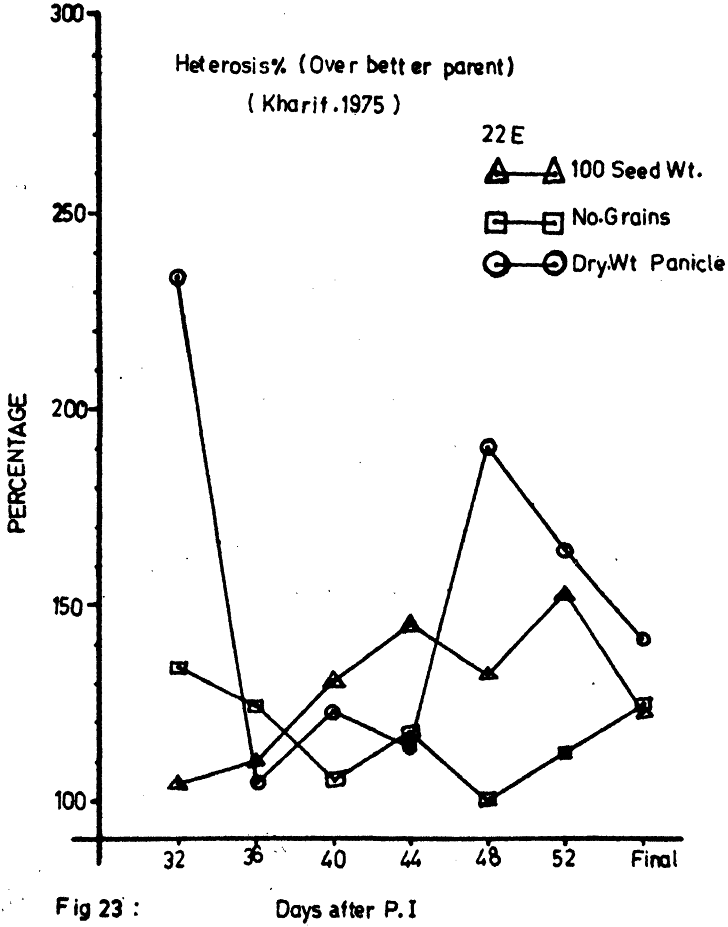


Fig 23 :

anthesis show negative correlation with primary branch length (r=−.87**). GS1 shows positive correlation with days to anthesis (r=.83**). GS3 is positively associated with 100 seed weight (seed size) (r=0.85) (Table 11).

TABLE 11. Correlation matrix (r) — Kharif 1975

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Panicle length (cm)	1													
2. Node number	.95**	1												
3. No. of Primary branches	.24	−.01	1											
4. Primary branch length (cm)	.85**	.72	.59	1										
5. No. of secondary branches	.27	.03	.84*	.69	1									
6. Grain number	.31	.09	.88**	.68	.94**	1								
7. Head weight (g)	.09	−.03	.71	.45	.71	.87**	1							
8. Grain weight (g)	.08	−.06	.76*	.47	.79*	.92**	.99**	1						
9. Husk weight (g)	−.19	−.21	.31	.09	.49	.63	.83**	.82**	1					
10. 100 seed weight (g)	−.30	−.25	.30	−.32	.20	.39	.78*	.72	.71	1				
11. Days to anthesis	−.72	−.56	−.65	−.87**	.58	−.51	−.25	−.28	.26	.11	1			
12. GS 1	−.47	−.26	−.57	−.56	−.43	−.28	.13	.05	.56	.48	.83**	1		
13. GS 2	−.57	−.61	−.30	−.70	−.38	−.49	−.64	−.57	−.39	−.54	.53	−.03	1	
14. GS 3	−.28	−.32	.52	.16	.45	.49	.72	.71	.49	.85**	−.24	.06	−.52	1

*Significant at 5% level
**Significant at 1% level

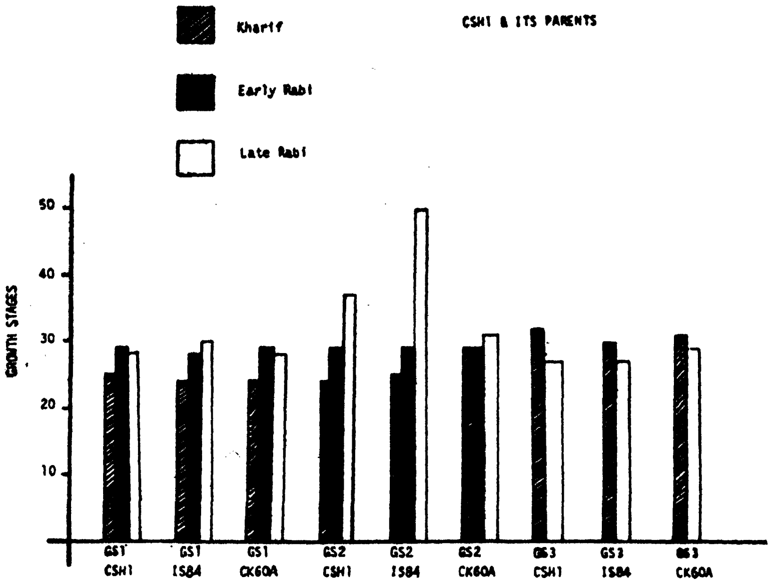


Fig. 24 : Growth stages of C S H 1 & its parents at different seasons (KHARiF-1975)

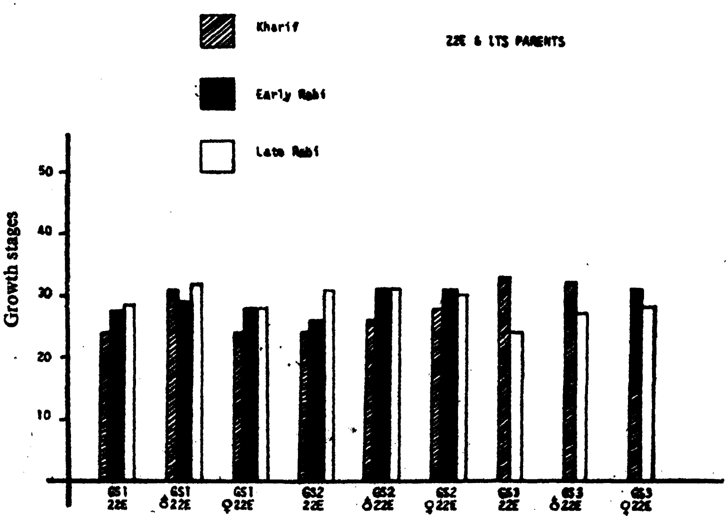


Fig. 25 : Growth stages of 22 E & its parents at different seasons (KHARIF-1975)

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