

SYNCHRONIZATION STUDIES IN PARENTAL LINES OF RICE HYBRIDS

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SYNCHRONIZATION STUDIES IN PARENTAL LINES OF RICE HYBRIDS

*Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfilment of the requirements for the*

Degree of

MASTER OF SCIENCE (AGRICULTURE)

in

SEED SCIENCE AND TECHNOLOGY

By

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CERTIFICATE

*This is to certify that the thesis entitled “**SYNCHRONIZATION STUDIES IN PARENTAL LINES OF RICE HYBRIDS**” submitted by **Mr. VEERANAGOUDA PATIL**, for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **SEED SCIENCE AND TECHNOLOGY** to the University of Agricultural Sciences, Dharwad, is a record of research work carried out by him during the period of his study in this university, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.*

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Introduction

I. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple cereal food crops. Rice stands second in the world after wheat in area and production. It occupies an area of 155.12 m.ha with an annual production of 596.48 m tonnes (Anon., 2000a). Among the rice growing countries, India ranks first in area, followed by China and Bangladesh. Rice is the leading cereal in India with an area of 44.8 m.ha and a production of 131.2 m tonnes annually (Anon., 2000a). In Karnataka, rice is cultivated in an area of 1.38 m.ha with an annual production of 3.33 m. tonnes (Anon., 1999a).

Although India achieved food self sufficiency during past decade, the country must increase food production every year to meet the demand of growing population and to maintain self sufficiency. To achieve this the production of rice has to be increased. The yield levels of high yielding varieties have become stagnant. The rice hybrids are known to enhance the yield by 15-20 per cent over high yielding varieties. Hence, hybrid rice cultivation, is of the most feasible way of increasing rice production (Viramani, 1998).

Inspite of yield advantage and many hybrids released for cultivation, the extent of area coverage under hybrid rice cultivation in our country is not comparable to China, in which more than 50 per cent of the rice area is covered under hybrids (Gangadharaiiah and Radhakrishna, 1997). Hence there is immense potential to increase the area

under hybrids and concurrently the total production of rice in our country. However, this is possible only when hybrid seed production practices are standardized under different agro-climatic situations. The success of the hybrid rice seed production, mainly depends on the availability of better quality parental seeds. The multiplication of CMS lines is influenced by various factors such as agro climatic region, sowing season, synchronization in flowering and supplementary pollination techniques etc.

The flowering behaviour of the parental lines of rice hybrid varies with genotype, environmental conditions and age of the seedlings etc., leading to non-synchrony in flowering. Determining the seeding interval between two parents in any hybrid combination at a given location and season is one of prime importance for achieving perfect synchronization in a hybrid rice seed production or in CMS line multiplication. The difference in flowering days is determined by different methods like Growth Duration Difference (GDD), Leaf Number Difference (LND) and Effective Accumulated Temperature Difference (EAT) methods.

Growth duration method is very simple and easy to adopt, but it is highly influenced by temperature and other environmental conditions. Unlike growth duration, the leaf number of a given variety is found to be relatively stable over the season and year (Jagadeesha, 1997). Leaf number method is considered more reliable, since this is based on physiological growth and age of the plant (Anon., 1995a). Therefore, at the

places where temperature fluctuations are very high or the varieties involved in hybrid seed production are sensitive to temperature, GDD method is not reliable (Viraktamath, 1995). Under these circumstances, the EAT method can be conveniently used. From physiological point of view, the range of temperature from 12-30°C only is useful to the plant, which influences flowering process. Every variety requires a specific quantum of temperature to reach the flowering stage. The EAT of a given variety remain relatively stable irrespective of time of seeding.

Production of hybrid seed and maintenance of CMS lines involve crossing of different parents, which is possible only when they flower simultaneously. Marked differences in flower synchronization were observed between CMS lines and their maintainers and in commercial F₁ seed production. Though, maintenance of cytosterile line is practiced involving isogenic lines, they often may or may not have same duration for flowering under a particular condition. Most of the CMS lines used to develop the hybrids in India have been developed by utilizing the sterile source of cytoplasm from *Wild Abortive*. Because of this, it is believed that the isogenic lines IR58025A and IR58025B differ with respect to days to flowering. Hence, it becomes obligatory to adjust seeding dates of these parents for obtaining a synchronous flowering.

Synchronization of flowering between parental lines assumes greater significance as the seed set on female parent depends on the amount of pollen supplied from the male parent during flowering period.

This problem could be overcome by staggered sowing of male parents based on their flowering behaviour. In spite of adjusting the sowing dates, the problem of non-synchrony in flowering of parental lines is observed because of differential response of parents to change in location and season. Therefore, it is essential to adjust the flowering of parental lines after observing the difference at the primordial development stage. Some chemicals like gibberellic acid, urea, phosphorus, etc., are found to be useful to some extent in adjusting the flowering of rice (Halaswamy *et al.*, 1997b). Apart from these, disturbing the established seedlings by way of giving a jerk can also be practiced for delaying the flowering.

With this background, the present investigation entitled “Synchronization studies in parental lines of rice hybrids” was initiated with the following objectives.

1. To find out seeding intervals through growth duration difference, leaf number difference and effective accumulated temperature difference methods
2. To find out techniques for getting better synchronization in flowering, seed yield and quality of CMS line of rice hybrid

Review of Literature

II. REVIEW OF LITERATURE

Synchronization in flowering between parental lines is a crucial factor in achieving higher hybrid or parental seed yields. The knowledge on flowering days of parental line is essential for adjusting sowing dates of parents. In spite of adjusting seeding dates of the male and female parents based on their maturity duration, often we come across the problem of non-synchrony owing to differential behaviour of the parental lines under different environmental conditions. Hence, it is essential to find out way to manipulate flowering once panicle initiation take place (Yogeesha *et al.*, 2000).

In this chapter, an effort has been made to review the information mainly on synchronization of flowering and different methods adopted to know the flowering days for fixing the seeding interval. Besides, all the available literature published to tackle this problem of non-synchronization in flowering and poor seed set through agronomic and cultural practices is also presented here. Wherever the information is lacking on rice, the information on related crops are reviewed.

2.1 FIXING SEEDING INTERVALS BY GROWTH DURATION, LEAF NUMBER AND EFFECTIVE ACCUMULATED TEMPERATURE DIFFERENCE METHODS

Fixing seeding interval of the parents sowing is very essential to achieve synchronization of flowering between the parental lines. In rice, apart from regular method of growth duration, other methods *viz.*, leaf

number and effective accumulated temperature difference methods are being used to find out the flowering days of parental lines based on leaf number and total effective temperature requirement of the parents (Vijayakumar and Viraktamath, 1997). These methods are closely associated with each other. Among them, leaf number difference method is more reliable and can be used for finer adjustment so as to obtain proper synchronization between parental lines (Jagadeesha, 1997).

2.1.1 Growth duration difference method

Flowering behaviour of CMS and restorer lines of rice hybrids varied with locations. The flowering of CMS lines (IR58025A and IR62829A) was early at Calcutta and was late at Mandya (Anon., 1995b).

Sukhpalsingh *et al.* (1996) reported that growth duration method could be used for determining seeding intervals to ensure synchronization of flowering if sowing is taken up under definite time period. Otherwise, the other two methods *viz.*, leaf number and EAT should be used to find out the seeding interval.

Jagadeesha (1997) recorded the growth duration difference of 18 and 19 days between IR58025A/IR9761-19-01R (KRH-1), two and four days between IR58025A/KMR-3 (KRH-2) during summer and *kharif* seasons, respectively.

The CMS line (IR58025A) of KRH-2 rice hybrid, female parent (IR58025A) flowered eight days later than the maintainer line (IR58025B) under Mandya conditions (Anon., 1997).

Krishnamurthy *et al.* (1998) in a study on seed production of KRH-2 rice hybrid, observed that the male parent KMR-3 was earlier in flowering by eight days compared to IR58025A under Mandaya conditions.

Viraktamath *et al.* (1998) reported that the parental lines of rice hybrids flowered earlier during wet season compared to dry season.

Biradarpatil (1999) observed early flowering of IR58025B by six days compared to IR58025A under Dharwad conditions.

2.1.2 Leaf number difference method

Wangfeng *et al.* (1993) observed that number of leaves produced till heading varied in four male sterile lines of rice. The CMS line Qing-Er-A had more number of leaves on the main culm (15.54), where as Zhao-Tai-A has less number of leaves (14.50).

To achieve perfect synchrony in flowering between the female (IR58025A) and male (IR10198) parents, the CMS line IR58025A should be seeded 11 days before seeding of restorer line. In case of IR58025A and Vajram, the female parent IR58025A has to be seeded when Vajram attains leaf number of 3.3 for better nicking (Anon., 1995a).

The leaf number of 17.91 and 16.08 was observed in IR58025A and IR58025B, respectively, from seeding till 50 per cent flowering under Faizabad conditions (Anon., 1995b), where as, under Coimbatore conditions, IR58025A and IR58025B recorded a leaf number of 15.75 and 16.0 for days to 50 per cent flowering (Anon., 1996b).

The studies under taken by Jagadeesha (1997) at Khatalgeri revealed that for taking up of seed production of KRH-2 rice hybrid, the female parent (IR58025A) should be sown when the male parent (KMR-3) has produced 1.2 and 0.94 leaves for achieving nicking in flowering during summer and *kharif* seasons, respectively. Where as, seed production of KRH-1 rice hybrid the male parent (IR9761-19-01R) should be sown when the female parent (IR58025A) produces 2.63 and 3.17 leaves during summer and *kharif*, respectively.

Nguyen *et al.* (1998) reported that under Vietnam conditions, sowing of female parent (Zhen Shan 97A) should be carried out when the male parents Gui 99 and Minghui 63 reaches 5.5 and 6.4 leaf stage, respectively.

Krishnamurthy *et al.* (1998) suggested that female parent (IR58025A) should be sown when the male parent (KMR-3) has produced two leaves for achieving nicking in flowering in seed production of KRH-2 rice hybrid.

Vijayakumar *et al.* (1998) reported that growth duration of CMS and restorer lines fluctuated from season to season, while the leaf number of these lines did not vary and hence the leaf number difference method could be used for adjusting sowing dates. Similarly, Viraktamath *et al.* (1998) observed variation in days to flowering of parental lines with location and season, where as the leaf number of a particular genotype remain fairly stable over the season and location.

Under Kanpur conditions a leaf number difference of 1.56 between IR58025A and IR40750R was observed and hence the CMS line IR58025A should be seeded later, when IR40750R produces 1.56 leaves in the nursery to achieve perfect synchrony (Anon., 2000b).

Parents of rice hybrid CORH-1 differed in leaf number to achieve the flowering. The female parent IR58025A has to be sown after the male parent UPRI92-133 reaches two leaf stage in the nursery (Anon., 2000c).

2.1.3 Effective accumulated temperature difference method

Xu and Li (1988) reported that parents of the rice hybrid, Shan Yan-2 differed in EAT requirement to achieve the flowering. The female parent Zhen Shan 97A has to be sown later, after the male parent IR24 to achieve the EAT of 342°C for getting better synchrony in flowering between the parents.

Sowing of maintainer line IR58025B should be carried out when the EAT of CMS line IR58025A reaches 72°C to achieve synchrony in flowering under Hyderabad conditions (Anon., 1994).

An EAT of 1401°C and 1536°C is required for PMS2A and PBR29 lines, respectively, for achieving 50 per cent flowering under Hyderabad conditions (Anon., 1995b).

The total EAT requirement for achieving flowering differed between IR62829A and IR62829B. The maintainer line IR62829B should be sown when the CMS line (IR62829A) reaches an EAT of 21°C (Anon., 1996b).

Jagadeesha (1997) reported that parents of rice hybrid, KRH-2 differed in EAT requirement to achieve the flowering. The female parent IR58025A has to be sown later, after the male parent (KMR-3) achieves an EAT of 61°C.

The CMS line of KRH-2 rice hybrid took more EAT to 50 per cent flowering during summer season than in *kharif* (Anon., 1999b).

2.2 TECHNIQUES FOR SYNCHRONIZATION OF FLOWERING

Flowering date of the parental lines can be adjusted by staggered planting or by differential application of nitrogen, phosphorous, 2, 4-D, GA₃, IAA or ethrel, if the panicle initiation stage of the parental lines is found non-synchronous (Huang *et al.*, 1994).

2.2.1 Influence of staggered planting on synchronization of flowering

The staggered sowing of male parent either early or late is practiced to achieve the synchrony in flowering if the difference is more than 4-5 days.

Liu *et al.* (1984) suggested that male parent should be transplanted on three dates with an interval of 11 days between the first and third to prolong the full flowering period instead of transplanting on two dates at eight days interval.

Staggered sowing of B lines on different dates gave higher seed set on five CMS lines. The earliness or lateness and the time gap required varied with the lines (Meghachandrasingh, 1986).

Rangasamy and Sreerangasamy (1988) reported that perfect synchronization of flowering was achieved by pruning the alternate hills of Zhen Shan 97B line, 25 days after planting during multiplication of Zhen Shan 97A. Pruned hills flowered one week later to non pruned hills and supplied continuous pollen.

Ramachandra (1989) observed higher seed set (6.97%) on female parent (Intan mutant A) by sowing male parent (IR27315) 17 days earlier to female compared to sowing on the same day (1.63%).

Shanbhogue and Mahadevappa (1991) with the study of seed production in promising rice hybrid, Intan mutant A x ARC11353, suggested early sowing of male parent by 19, 24 and 29 days than the female parent to get better flower synchrony and higher seed set.

Deshpande (1993) during the F₁ hybrid seed production (IR62829A x IR9761-19-01R) observed that sowing of male parent nine days later than female parent was found to synchronize in flowering. Another sowing of male parent on 13th day was necessary to assure continuous pollen supply.

Halaswamy *et al.* (1997a) observed proper synchronization in flowering of parents of rice hybrid with three staggered sowings of male parent (five days early, simultaneous and five days later) compared to the other combinations of suggested sowing.

Jagadeesha (1997) observed early flowering of IR58025B line by eight days compared to IR58025A under Kathalgeri conditions, and

recommended for staggered sowing of IR58025B line on seventh and tenth day after sowing of IR58025A for multiplication of female parent.

Krishnamurthy *et al.* (1998) in a study on seed production of KRH-2 rice hybrid, suggested that the male parent should be sown eight days earlier than female to achieve synchronization in flowering between the parents under Mandya conditions.

Krishnamurthy and Nagalika (1999) observed early flowering of IR58025B by five days compared to IR58025A, and recommended that IR58025B should be sown five days of IR58025A to get perfect flowering synchrony.

Two staggered sowing of B line and three staggered sowings of R lines at two to three days interval after seeding of A line has been recommended for seed production of female parent and Pant Shankar Dhan-1, rice hybrid under Pantnagar conditions (Anon., 2000c).

2.2.2 Effect of nitrogen on flower synchronization

Generally it is observed that additional application of nitrogen delays the flowering in rice, since it is nitro negative crop.

Venkataraman and Raja (1971) observed that application of nitrogen upto 96 kg per ha recorded higher values of flowering index in rice. However, further increase in nitrogen level upto 120 kg per ha reduced the index value indicating delayed flowering.

Xiong (1987) observed delay in heading date in *indica* rice cultivar with increase in nitrogen rate.

Application of quick releasing nitrogenous fertilizers like urea at two per cent in spray form and soil application of 30-40 kg nitrogen per ha could be practiced to delay the flowering in hybrid seed production of rice (Viraktamath, 1995).

Spraying of nitrogenous fertilizer to early flowering parent for getting flowering synchrony was reported by Xiaojin (1995).

Nitrogen application to restores line of rice (IR13419-113-IR) resulted in two days delayed flowering (Halaswamy *et al.*, 1997b).

Yukun *et al.* (1997) reported that the application of 45 kg urea per ha to the male parent of rice delayed the flowering by two to three days.

Lingaraju *et al.* (1998) noticed that application of urea 20 kg per ha to the base of the plants at the full boot leaf stage delayed 50 and 100 per cent flowering by two days in IR58025A.

Biradarpatil (1999) reported that additional application of nitrogen (25 kg/ha) to soil coupled with foliar spray of urea (2.0%) delayed the 50 per cent flowering of IR58025A by 4.7 days and increased the hybrid seed yield by 54.7 per cent, over control.

2.2.3 Effect of gibberellic acid on flower synchronization

Naturally occurring hormones play an important role in the process of flowering. This is because of the fact that the exogenous application of growth regulators like gibberellic acid are commonly used to promote flowering.

Early flowering was noticed with the application of gibberellic acid in ragi (Appalanaidu *et al.*, 1961) and in sorghum (Joshi, 1976 and Malali 1979).

Gibberellic acid application at 200 ppm concentration induced early flowering by one day in February, by seven days in January and August in sorghum (Vadivelu *et al.*, 1984).

Xiaojin (1995) reported that GA₃ application has advanced the heading by two days in parents of hybrid rice.

Foliar spray of 60 ppm GA₃ to the seed parent IR58025A at five per cent anthesis resulted in one day early flowering (Halaswamy *et al.*, 1997b).

Lingaraju *et al.* (1998) observed the advancement of 50 per cent and full flowering in IR58025A by three days and five days, respectively, with the application of 60 ppm GA₃ at full boot stage.

Biradarpatil (1999) reported that GA₃ (100 ppm) application at panicle initiation stage advanced the 50 per cent flowering by 3.7 days in the male parent of rice hybrid KRH-2.

Yogeesha *et al.* (2000) observed that foliar spray of GA₃ (180 g/ha) to male parent IR40750 at five per cent anthesis resulted in four days early flowering.

2.2.3.1 Effect of gibberellic acid on growth and seed yield

Gibberellic acid plays a very important role in hybrid rice seed production as evident by the experience of the Chinese over the last two decades in solving the problem of poor panicle exertion and seed set on the *indica* CMS lines that have been developed based on WA cytoplasm.

Buu and Huang (1980) observed that GA₃ application (50 ppm) increased the plant height in semi dwarf cultivars of rice. It also increased number of filled spikelets per panicle and seed set percentage.

A study conducted at IRRI (Anon., 1986a) with growth regulators on morphological and floral traits indicated that, GA₃ increased the duration of opening of floret and spraying of 60 ppm GA₃ at initial heading stage increased seed yield significantly during dry season.

Studies of Kaur and Singh (1986) indicated increase in the number of vascular bundles and size of the phloem in young peduncles with the spray of GA₃, which facilitated better translocation of metabolites from source to sink. This resulted in increase in number of productive tillers, number of filled spikelets and 1000 seed weight.

Spraying of 150 g GA₃ per ha in three or four sprays with the concentration ranging from 40-60 ppm at early heading stage increased the seed set in female parent upto 65 per cent in China (Shengqui, 1988).

Duan and Ma (1992) observed increase in plant height of CMS line Zhenshan 97A with foliar spray of GA₃. They also observed higher seed yield with GA₃ spray.

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Deshpande (1993) observed the beneficial effect of GA₃ (60 ppm) in increasing the plant height, productive tillers per plant, panicle length, panicle exertion percentage, filled spikelets per plant, seed set percentage and the seed yield. The test weight also increased significantly with GA₃ application.

Bong *et al.* (1994) observed that GA₃ spray increased the plant height, number of filled spikelets, outcrossing rate and hybrid seed yield of rice significantly over control.

Suprihantno *et al.* (1994) observed increase in number of productive tillers per plat, number of filled spikelets per panicle, seed set and seed yield of rice hybrids with GA₃ spray (60 ppm) at panicle initiation stage.

Thiagarajan *et al.* (1994) recorded the highest seed yield in CMS lines of paddy with GA₃ spray at 100 g per ha in split doses. The boot leaf angle increased with GA₃ application ($69\pm 18^\circ$) over the control ($38\pm 7^\circ$). The increase in seed yield was due to increased boot leaf angle and panicle exertion.

Virmani (1994) reported that response of GA₃ is genotype specific and male sterile lines respond better than fertile lines. GA₃ helps in keeping the spikelets open for longer time which increases the receptivity of stigma upto seven days in CMS lines.

Halaswamy *et al.* (1997b) noticed increased plant height, number of productive tillers per plant, number of filled spikelets per panicle, seed set

percentage and seed yield of hybrid rice with the application of GA₃ @ 60 ppm. Beneficial effect of GA₃ in seed production of rice hybrid for increasing the yield and yield attributing characters were also observed by Jagadeesha (1997); Jagadeeshwari *et al.* (1998); Ponnuswamy *et al.* (1998) and Birdarpatil (1999).

Thirthalingappa *et al.* (1999) reported that GA₃ application (200 ppm) to CMS lines increased the plant height, number of productive tillers per plant, panicle exsertion percentage, filled spikelets per plant, seed set percentage and seed yield.

2.2.3.2 Effect of gibberellic acid on seed quality parameters

Duan and Ma (1992) observed significantly higher germination at first count with the increased levels of GA₃ in hybrid rice. However, it was not significant at the final count.

Deshphande (1993) recorded increased germination, field emergence, seedling length and vigour with the application of GA₃ (60 ppm) at two per cent flowering to cytotsterile line of rice.

Revansiddappa (1996) observed marginal increase in germination, field emergence and vigour index with the spray of GA₃ (100 ppm) over control at panicle initiation stage in upland rice cv. Amrut. However, significant improvement in seed quality parameters was observed when the seeds were soaked in GA₃ solution.

Biradarpatil (1999) observed significant increase in germination, seedling length, dry weight of seedlings and vigour index with foliar spray of GA₃ (75 g/ha) during five per cent heading stage.

2.2.4 Effect of phosphorus on flowering and seed yield

Phosphorus is known to enhance the flowering by early induction of reproductive phase.

Venkataraman and Raja (1971) reported that application of phosphorus at 48 and 72 kg per ha hastened the flowering in rice at nitrogen level upto 48 kg per ha. At higher 'N' levels, the effect of 'P' was unsteady.

Kailasam *et al.* (1978) observed that nursery manuring with di-ammonium phosphate and main field manuring of phosphorus were independently contributed in hastening the flowering of rice.

Mengel *et al.* (1979) observed significant advancement in heading of rice cv. Labelle with the soil application of phosphorus prior to sowing.

Viraktamath (1995) reported that spraying of one per cent solution of phosphate fertilizer advances the flowering of late parent of rice hybrids.

Xiaojin (1995) suggested for spraying of KH₂PO₄ and top dressing of phosphorus and potash to the late parent of hybrid rice.

Halaswamy *et al.* (1997b) noticed one day early flowering in male line IR13419-113-IR due to the application of phosphorus.

Yukun *et al.* (1997) suggested the spraying of two per cent KH_2PO_4 to induce early flowering in female parent of hybrid rice.

Lingaraju *et al.* (1998) in IR58025A line observed delayed flowering by two days with the application of 20 kg phosphorus per ha at the full boot leaf stage, however, flowering duration decreased by three days.

Biradarpatil (1999) observed that foliar spray of single super phosphate (1.0%) at panicle initiation stage enhanced the flowering by 3.2 days and increased the seed yield by 32 per cent, over control.

2.2.5 Effect of jerking on flowering

The literature on effect of jerking of seedlings to achieve flowering synchrony is meagre and hence the related information on other crops has been reviewed. Jerking of seedlings of early flowering parent is known to delay the flowering in rice.

In pearlmillet, the early flowering parent could be delayed by jerking the earhead at boot stage (Anon., 1986b).

Halaswamy *et al.* (1997b) reported that retransplanting of transplanted seedlings of restorer line after one week delayed the 50 per cent flowering by five days.

Nguyen *et al.* (1998) reported that disturbing (cutting) the roots of established seedlings of restorer line of rice hybrid delayed the 50 per cent flowering.

Agrawal (1998) recommended jerking of the early flowering earhead at boot leaf stage to delay the flowering in seed production of pearlmillet.

Material and Methods

III. MATERIAL AND METHODS

The details of the materials used and methods adopted in conducting the experiments are described below.

3.1 LOCATION OF THE EXPERIMENTAL SITE

The field experiments were conducted at Main Research Station, Dharwad and Agricultural Research Station, Siruguppa during *kharif* season of 2000. Dharwad is situated at 15°17' North latitude, 75°05' East longitude and has an altitude of 781.8 m above mean sea level. Siruguppa is situated at 15°38' North latitude, 75°54' East longitude and at an altitude of 380 m above mean sea level.

3.2 CLIMATIC CONDITIONS

The monthly weather data during the period of investigation and average of 50 years recorded at the meteorological observatory of Main Research Station, Dharwad are presented in Table -1, and that of Agricultural Research Station, Siruguppa in Table -1A.

3.3 SOILS

The soils of the experiment sites were clay loam and black soils. The composite soil sample from each experimental site was collected from 0 to 15 cm depth before the start of the experiment and was analysed for different physical and chemical characteristics by following the standard procedure (Jackson, 1967). The characters are presented in Appendix 1.

Table 1. Monthly meteorological data for the year and average of 50 years (1950-99) recorded at the meteorological observatory of the Main Research Station, UAS, Dharwad

Months	Rainfall (mm)		Temperature (°C)				Mean relative humidity (%)	
	2000	1950-99	Maximum		Minimum		2000	1950-99
			2000	1950-99	2000	1950-99		
January	0.00	0.10	30.60	29.18	15.10	14.09	48.00	64.22
February	0.00	0.00	32.20	34.66	15.70	15.96	52.00	51.24
March	0.00	7.52	35.20	35.77	18.50	18.79	47.00	57.12
April	44.10	47.98	37.30	37.10	21.50	21.38	57.00	78.71
May	45.40	85.39	33.90	36.64	21.10	21.46	67.00	67.16
June	50.70	114.35	29.00	29.49	21.30	21.20	79.00	82.06
July	125.20	153.67	26.80	27.05	20.40	20.96	81.00	88.02
August	50.40	99.64	27.20	27.02	20.20	20.64	81.00	86.95
September	132.10	104.43	29.00	28.73	20.40	20.17	76.00	83.00
October	88.30	136.33	29.50	30.11	20.20	19.25	77.00	77.04
November	0.00	34.43	30.40	29.37	16.9	15.38	63.00	68.79
December	3.00	5.82	28.30	29.17	13.40	13.41	58.00	64.71
Total	539.20	789.45						

Table 1A. Meteorological data during the crop growth at Siruguppa (January to December, 2000)

Months	Rainfall (mm)	Temperature (°C)		Relative humidity (%)
		Maximum	Minimum	
January	-	31.6	17.3	62.5
February	-	33.1	19.6	69.6
March	-	36.4	20.4	53.1
April	-	39.8	24.5	62.8
May	69.4	39.5	25.6	67.3
June	65.6	33.3	24.9	78.6
July	65.0	32.6	24.0	76.8
August	185.6	36.5	23.9	78.0
September	88.0	33.0	23.0	76.8
October	169.2	31.5	22.9	85.7
November	-	38.2	21.3	79.7
December	2.6	29.1	15.5	-

3.4 DESCRIPTION OF THE PARENTS

The salient features of the parental lines are given in Table 2.

3.5 EXPERIMENTAL DETAILS

3.5.1 Experiment 1: Fixing seeding intervals through growth duration difference (GDD), leaf number difference (LND) and effective accumulated temperature difference (EAT) methods

The experiment was carried out during *kharif* 2000 at two locations. The details of the treatments are given below.

3.5.1.1 Treatment details

- A Parental lines :
- | | | |
|----------------|---|---------------|
| P ₁ | - | IR58025A |
| P ₂ | - | IR58025B |
| P ₃ | - | IR62829A |
| P ₄ | - | IR62829B |
| P ₅ | - | IR40750R |
| P ₆ | - | KMR-3 |
| P ₇ | - | IR9761-19-01R |
- B Locations :
- | | | |
|----------------|---|--|
| L ₁ | - | Main Research Station, Dharwad |
| L ₂ | - | Agricultural Research Station, Siruguppa |

3.5.1.2 Experimental design

The experiment was laid out in Randomised Block Design with Factorial concept with three replications.

Table 2. Salient features of parental lines of rice hybrids

Characters	Parental lines						
	IR58025A	IR58025B	IR62829A	IR62829B	IR40750R	IR9761-19-01R	KMR-3
Plant height (cm)	65-70	70-75	65	74	78	70-75	110-120
Anther colour	White occasionally one is yellow	Yellow	White	Yellow	Yellow	Yellow	Yellow
Awns	Tendency for awning	Tendency for awning	Partial awns	Partial awns	Upper half panicle awned	Awns absent occasionally tendency for awning	Awns absent
Spikelets	Sterile	Fertile	Sterile	Fertile	Fertile	Fertile	Fertile
Days to 50% flowering	97-100	91-94	106	101	124	80-93	101-108
Crop duration (days)	130-132	125-128	138-140	134-138	155-159	112-115	135-138

3.5.1.3 Plot size: Gross Plot – 3.0 m x 3.0 m

Net Plot – 2.2 m x 2.4 m

3.5.1.4 Date of sowing: 18th July 2000

3.5.1.5 Seed source

Seeds were obtained from Directorate of Rice Research, Hyderabad and Regional Research Station, Mandya.

3.5.1.6 Cultural operations

3.5.1.6.1 Nursery techniques

The seedlings of all the parental lines were raised on dry seed bed nursery. The recommended cultural practices for raising the nursery of paddy were followed (Vidyachandra *et al.*, 1997).

3.5.1.6.2 Land preparation

Land was ploughed with mould board plough followed by clod crushing and harrowing to bring the soil to proper tilth. Levelling was done by wooden plank and the plots were laid out as per plan. Small field bunds were created around each plot.

3.5.1.6.3 Transplanting

The 30 days old seedlings were transplanted at a spacing of 15 cm between plants and 20 cm between rows was followed.

3.5.1.6.4 Fertilizer

Recommended dose of fertilizer *viz.*, 100:50:50 kgs of nitrogen, phosphorus and potash per hectare was applied. Half the dose of nitrogen, entire dose of potash and phosphorus was applied at the time of planting and the remaining 50 kg nitrogen was applied in two equal split doses, one at tillering and another at panicle initiation stage.

3.5.1.6.5 After care

Recommended cultural practices for raising healthy seedlings of paddy were followed (Vidyachandra *et al.*, 1997).

3.5.1.7 Collection of experimental data

3.5.1.7.1 Sampling procedure

Ten seedlings per replication from each genotype were selected at nursery and labelled for recording the leaf numbers. The observations on other parameters were recorded on randomly selected five plants in each replication.

3.5.1.7.2 Observations recorded

i. Plant height

The plant height at the time of harvest was measured from the base of stem at ground level to the tip of the main panicle and recorded in centimeters.

ii. Number of leaves

Total number of leaves produced by the main culm of the parents from seeding to 50 per cent flowering were recorded at three days interval starting from fully opened leaf, by following three division method of counting leaves. The values for the developing leaves are given keeping the fully opened previous leaf as reference. The rating given for the three division method are 0.2, 0.5 and 0.8 for leaf just emerged, leaf half opened and leaf almost opened, respectively (Viraktamath, 1995).

iii. Effective accumulated temperature (EAT)

The sum of effective temperature accumulated over a period from seeding to 50 per cent flowering is worked out by the following formula and expressed in degree celsius (Viraktamath, 1995).

$$\text{EAT} = (T-H-L)$$

Where, T - Mean daily temperature (°C)

H - The temperature over upper limit (30°C)

L - The temperature of lower limit (12°C)

iv. Angle of glume opening

The maximum angle between the lemma and palea during peak anthesis period was measured and recorded in degrees.

v. Days to panicle initiation

The number of days taken from sowing to the initiation of panicle was recorded as days to initiation of panicle.

vi. Days to initiation of flowering

The number of days taken from sowing to initiation of flowering was recorded as days to initiation of flowering.

vii. Days to 50 per cent flowering

The number of days taken from sowing to 50 per cent of the plants in the plot to flower was recorded as days to 50 per cent flowering.

viii. Days to completion of flowering

The number of days taken from sowing to completion of flowering in all the plants of the plot was recorded as days to completion of flowering.

3.5.2 Experiment 2: Effect of different techniques on flower synchronization of flowering, seed yield and quality of CMS line IR58025A of rice hybrid

The experiment was carried out during *kharif* 2000 at Main Research Station, Dharwad. The treatment details are given below.

3.5.2.1 Treatment details

Parents : IR58025A (A line)

: IR58025B (B line)

- T₁ - Sowing of A and B line on same day (control)
- T₂ - Staggered sowing of B line three days later than A line
- T₃ - Staggered sowing of B line five days later than A line
- T₄ - T₁ + Foliar spray of two per cent urea to B line at panicle initiation
- T₅ - T₁ + Foliar spray of 100 ppm gibberellic acid (GA₃) to A line at panicle initiation
- T₆ - T₁ + Foliar spray of one per cent single super phosphate (SSP) to A line at panicle initiation
- T₇ - T₁ + Jerking of B line seedlings at panicle initiation

3.5.2.2 Experimental design

The experiment was laid out in Randomised Block Design with three replications.

3.5.2.3 Plot size

Gross – 3.0 m x 3.0 m

Net – 2.2 m x 2.4 m

3.5.2.4 Cultural operations

3.5.2.4.1 Nursery techniques

The seedlings of both CMS and maintainer lines were raised on dry bed nursery. The maintainer line (B-line) was staggered sown as per the treatments.

3.5.2.4.2 Transplanting

The 30 days old seedlings were transplanted at the row ratio of 4:1 between CMS to maintainer parent. The spacing of 15 cm between plants of both CMS and maintainer lines, 15 cm between the rows of female parent and 20 cm between maintainer parent was followed. Single seedling of female and two to three seedlings of maintainer parent were planted per hill.

Barrier isolation was provided between the treatments and around the experimental plots to check the movement of pollen by erecting polyline sheets of 2.0 m height.

3.5.2.4.3 Fertilizer application

Fertilizers were applied as per 3.5.1.6.4.

3.5.2.4.4 After care

After care was taken as per 3.5.1.6.5

3.5.2.5 Collection of experimental data

3.5.2.5.1 Sampling procedure

Five plants per plot of the female parent (CMS line) were randomly selected in each treatment and labelled. Observations on growth and yield parameters were recorded on these plants. Observations on flowering was recorded on both the parents.

3.5.2.5.2 Observations on growth and yield parameters

i. Plant height

The plant height was recorded as per 3.5.1.7.2.i

ii. Number of productive tillers per plant

All the ear bearing tillers were counted from the labelled culm to calculate mean number of productive tillers per plant.

iii. Number of filled spikelets per panicle

The filled spikelets per panicle were counted and expressed in number.

iv. Seed set

The seed set was computed by using the following formula and expressed as seed set percentage.

$$\text{Seed set (\%)} = \frac{\text{Number of filled spikelets}}{\text{Total number of spikelets}} \times 100$$

v. Seed yield per plant

The seed yield obtained per plant was sun dried to 12 per cent seed moisture and weighed and expressed in grams per plant.

vi. Seed yield per hectare

The seeds obtained from the corresponding net plots were sun dried and weighed. The seed yield per hectare was computed and recorded in kilograms.

vii. Seed recovery percentage

The seeds harvested from the net plot were processed using recommended sieve size of 2.8 mm (s) as top and 1.7 mm (s) as bottom screen. The portion of sample that retained over the bottom sieve was considered as good seed and weight was recorded. The seed recovery percentage was calculated by using the following formula.

$$\text{Seed recovery (\%)} = \frac{\text{Weight of seeds after processing}}{\text{Total weight of seeds before processing}} \times 100$$

viii. Test weight

Thousand seeds were counted manually from a sample drawn randomly from each treatment in four replications and weight was recorded in grams.

ix. Days to flowering

Observations on days to initiation of flowering, days to 50 per cent flowering and days to completion of flowering was recorded as per 3.5.1.7.2 – vi, vii and viii.

3.5.2.5.3 Observation on seed quality parameters

i. Germination percentage

The germination test was carried out by adopting the 'Between Paper' method as per the procedure of ISTA (Anon., 1996a). The number of normal seedlings were counted on 14th day (final count) of germination from all the replications. The average of four replications was expressed as germination percentage.

ii. Shoot length

Shoot length was measured from collar region to the apex in ten randomly selected 14 days old normal seedlings and the mean was recorded as shoot length in centimeters.

iii. Root length

The root length between collar region and the tip of root in ten randomly selected 14 days old normal seedlings was measured and the mean was calculated and expressed in centimeters.

iv. Dry weight of seedlings

Ten randomly selected seedlings for measuring shoot and root length were dried in an oven at $70 \pm 1^\circ\text{C}$ for 24 hours and after cooling, the seedlings weight was measured in milligrams.

v. Vigour index

Vigour index was computed by using the following formula and expressed in number (Abdul-Baki and Anderson, 1973).

Vigour index = Germination percentage x (Shoot length + Root length) cm

3.5.3 Statistical analysis of data

The data obtained from various periodical observations were subjected to statistical analysis. The analysis of variance and interpretation of data were done as per procedure given by Gomez and Gomez (1984). Levels of significant used in 'F' and 't' test was $P=0.05$. Critical difference (C.D) values were calculated only when the 'F' test was found significant.

Experimental Results

IV. EXPERIMENTAL RESULTS

The results of present investigation are presented in this chapter.

4.1 EXPERIMENT 1: FIXING SEEDING INTERVALS THROUGH GROWTH DURATION DIFFERENCE, LEAF NUMBER DIFFERENCE AND EFFECTIVE ACCUMULATED TEMPERATURE DIFFERENCE METHODS

4.1.1 Evaluation of parental lines for growth and floral traits

The results on plant height, angle of glume opening, days to initiation of panicle, days to 50 per cent flowering, days to completion of flowering and days to maturity recorded on different parental lines at Main Research Station, Dharwad is been presented here.

4.1.1.1 Plant height (cm)

The results on plant height presented in the Table 3 indicates significant variation in plant height amongst the parental lines.

Significantly higher plant height was observed with KMR-3 (110.1cm) followed by IR9761-19-01R (73.3cm). The lowest plant height was observed with IR40750R (63.2cm). There was no significant difference in plant height between the male sterile and maintainer lines.

4.1.1.2 Angle of glume opening (°)

The angle of glume opening did not differ significantly among the parental lines (Table 3). However, the restorer line KMR-3 has the widest

Table 3. Plant height, angle of glume opening in parental lines of rice hybrids

Parental lines	Plant height (cm)	Angle of glume opening (°)
IR58025A	65.2	21.6
IR58025B	67.3	21.2
IR62829A	65.9	22.1
IR62829B	66.6	22.0
IR40750R	63.2	21.8
KMR-3	110.1	23.2
IR9761-19-01R	73.3	21.4
Mean	73.1	21.9
S.Em±	2.2	0.5
C.D. (0.05)	6.8	NS

NS - Non-significant

angle of glume opening (23.2°) and the lowest angle of glume opening was observed with IR58025A (21.2°).

4.1.1.3 Days to panicle initiation

The data on days to initiation of panicle indicates significant differences due to parental lines (Table 4).

The restorer line (KMR-3) took significantly higher days to initiation of panicle (75.7) followed by IR40750R (68.0), while IR9761-19-01R took significantly lower number of days for panicle initiation (54.7). The other parental lines IR58025A, IR58025B, IR62829A and IR62829B took 66.3, 63.0, 65.3 and 63.0 days, respectively, for initiation of panicle.

4.1.1.4 Days to initiation of flowering

The data presented in Table 4 reveals significant difference in days to 50 per cent flowering between the parental lines.

The restorer parent, KMR-3 recorded significantly higher number of days to initiation of flowering (107.0), while IR9761-19-01R took significantly lower number of days (82.3) for initiation of flowering. The male sterile line (IR58025A) and maintainer line (IR58025B) differed significantly for days to initiation of flowering among themselves and there was 4.3 days difference between them, whereas IR62829A and IR62829B did not differ significantly among themselves for days to initiation of flowering.

Table 4. Days to panicle initiation, days to initiation of flowering, days to 50 per cent flowering and days to maturity in parental lines of rice hybrids

Parental lines	Days to panicle initiation	Days to initiation of flowering	Days to 50% flowering	Days to completion of flowering	Days to maturity
IR58025A	66.3	99.3	103.7	109.7	131.6
IR58025B	63.0	95.0	99.0	105.7	128.3
IR62829A	65.3	91.3	96.0	103.3	126.6
IR62829B	63.0	90.0	92.7	99.7	122.3
IR40750R	68.0	98.0	108.3	115.0	136.0
KMR-3	75.7	107.0	111.3	117.0	139.0
IR9761-19-01R	54.7	82.3	86.7	93.3	116.3
Mean	65.1	94.7	99.7	106.2	128.6
S.Em±	0.3	0.4	0.3	0.4	1.1
C.D. (0.05)	1.0	1.4	0.9	1.3	3.4

4.1.1.5 Days to 50 per cent flowering

The result presented in Table 4 indicates the significant influence of various parental lines on days to 50 per cent flowering.

All the parental lines varied significantly each other for days to 50 per cent flowering. The restorer line KMR-3 recorded significantly higher days to 50 per cent flowering (111.3) followed by IR40750R (108.3). Another restorer line IR9761-19-0R recorded significantly the lower number of days for 50 per cent flowering (86.7). The respective male sterile and maintainer lines differed significantly among themselves for days to 50 per cent flowering. There was a difference of 17.0, 7.6 and 4.6 days between the parents of KRH-1 (IR58025A x IR9761-19-01R), KRH-2 (IR58025A x KMR-3) and DRRH-1 (IR58025A x IR40750R).

4.1.1.6 Days to completion of flowering

The days to completion of flowering was influenced by different parental lines (Table 4).

All the seven parental lines varied significantly among themselves for days to completion of flowering. The restorer line, KMR-3 took significantly higher number of days to completion of flowering (117.0) followed by IR40750R (115.0), while IR9761-19-01R took minimum number of days (93.3). The other parental lines, IR58025A, IR58025B, IR62829A and IR2829B completed flowering in 109.7, 105.7, 103.3 and 99.7 days, respectively.

The data on days to maturity indicate significant differences between the parental lines (Table 4).

Among the parental lines, the days to maturity was significantly higher with KMR-3 (139.0) followed by IR40750R (136.0), while IR9761-19-01R recorded the minimum number of days (116.3) for maturity. The male sterile lines (IR58025A and IR62829A) and the maintainer lines (IR58025B and IR62829B) differed significantly among themselves for days to maturity amongst them the maintainer lines matured earlier than their respective CMS lines.

4.1.2 Fixing seeding interval

The observation recorded on days to 50 per cent flowering, leaf number and EAT at Dharwad and Siruguppa are presented here.

4.1.2.1 Days to 50 per cent flowering

The results presented in Table 5 (Fig. 1 and 4) indicates the significant influence of locations and parental lines on days to 50 per cent flowering.

All the parental lines varied significantly with each other for days to 50 per cent flowering. The restorer line KMR-3 recorded significantly higher days to 50 per cent flowering (113.3) followed by IR40750R (110.3). The another restorer line IR9761-1901R recorded significantly lower

number of days to 50 per cent flowering (90.1). The respective male sterile and maintainer lines differed significantly among themselves for days to 50 per cent flowering.

Among the locations, days to 50 per cent flowering was significantly higher at Siruguppa (103.8) than at Dharwad (99.7).

The interaction effect due to parental lines and locations was significant. The KMR-3 took higher number of days to 50 per cent flowering at Siruguppa (115.3), while IR9761-19-01R recorded the lowest number of days to 50 per cent flowering at Dharwad (86.7).

4.1.2.2 Number of leaves

The data on number of leaves recorded from seeding to 50 per cent flowering presented in Table 5 (Fig. 2 and 4) reveals significant differences among the parental lines and the locations.

Irrespective of production location, the average number of leaves produced by the genotype from seeding till 50 per cent flowering remained fairly stable. Among the parental lines, the restorer line KMR-3 produced significantly more number of leaves (15.7) followed by IR40750R (15.2). The CMS and maintainer lines, IR58025A (14.1) and IR58025B (13.3) differed significantly each other for number of leaves, whereas IR62829A and IR62829B did not differ significantly between themselves. The restorer line, IR9761-19-01R recorded significantly the lower number of leaves (9.9).

Table 5. Days to 50 per cent flowering, number of leaves and effective accumulated temperature of different parental lines as influenced by locations

Parental lines (P)	Days to 50% flowering			Number of leaves			Effective accumulated temperatures (°C)		
	L ₁	L ₂	Mean	L ₁	L ₂	Mean	L ₁	L ₂	Mean
IR58025A	103.7	107.0	105.3	14.0	14.2	14.1	1249.4	1454.2	1351.9
IR58025B	99.0	104.3	101.7	13.2	13.5	13.3	1207.4	1418.3	1312.8
IR62829A	96.0	99.3	97.7	10.2	10.5	10.3	1169.6	1355.4	1262.5
IR62829B	92.7	94.7	93.7	10.0	10.2	10.1	1131.0	1294.8	1212.9
IR40750R	108.3	112.3	110.3	15.0	15.5	15.2	1310.1	1511.8	1410.9
KMR-3	111.3	115.3	113.3	15.5	16.0	15.7	1346.3	1544.3	1445.3
IR9761-19-01R	86.7	93.7	90.1	9.9	10.0	9.9	1050.6	1277.3	1169.9
Mean	99.7	103.8	101.7	12.5	12.8		1209.2	1408.0	1309.5
Parental lines (P) S.Em±	0.3	0.6	0.3	0.1	0.2	0.1	4.0	12.1	6.3
C.D. (0.05)	0.9	1.9	1.0	0.5	0.6	0.3	12.5	37.4	18.3
Location (L) S.Em±			0.1			0.1			3.3
C.D. (0.05)			0.5			0.4			9.8
Interaction (PXL) S.Em±			0.5			0.1			8.9
C.D. (0.05)			1.5			NS			NS

NS - Non-significant ; L₁ - Dharwad, L₂ - Siruguppa,

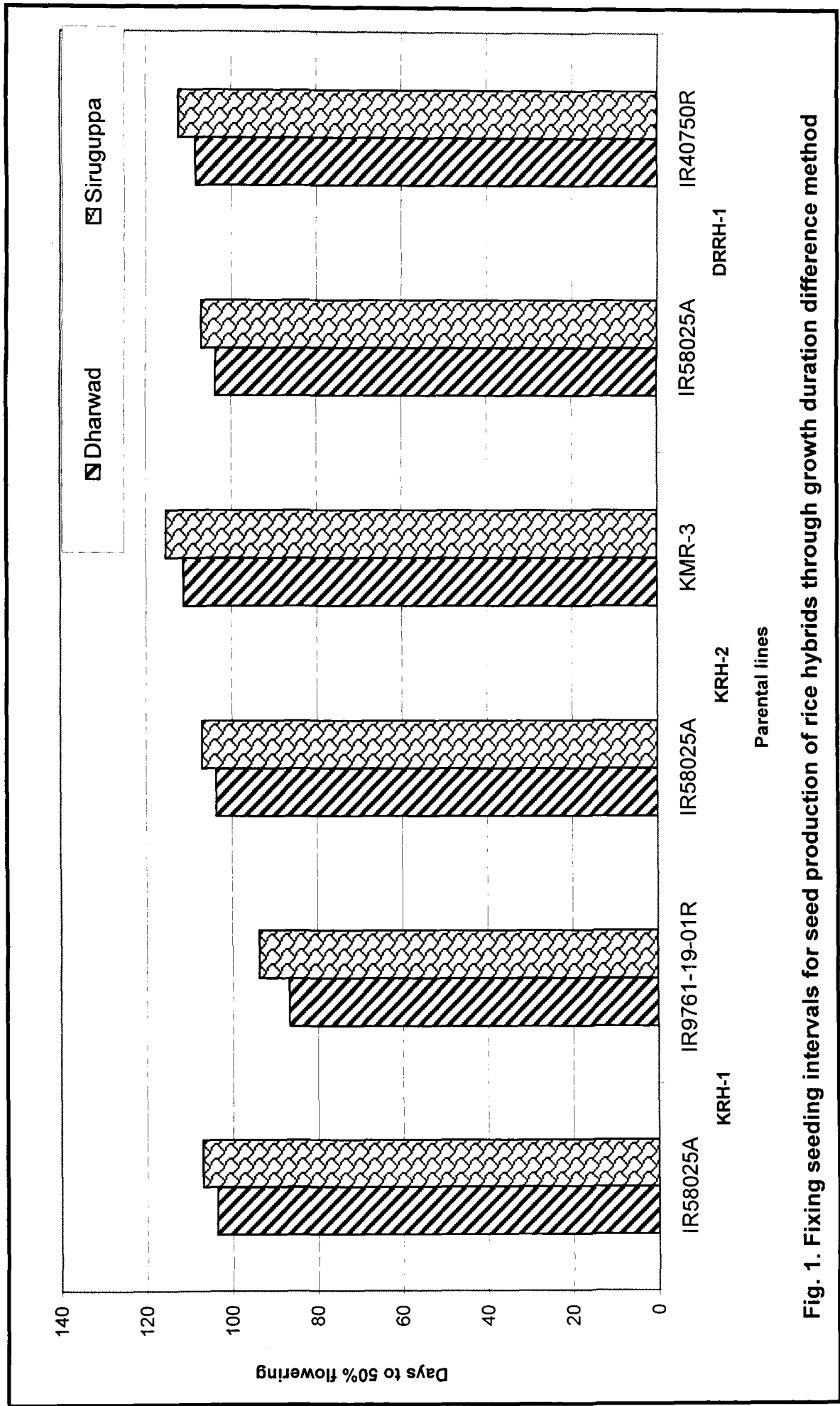


Fig. 1. Fixing seeding intervals for seed production of rice hybrids through growth duration difference method

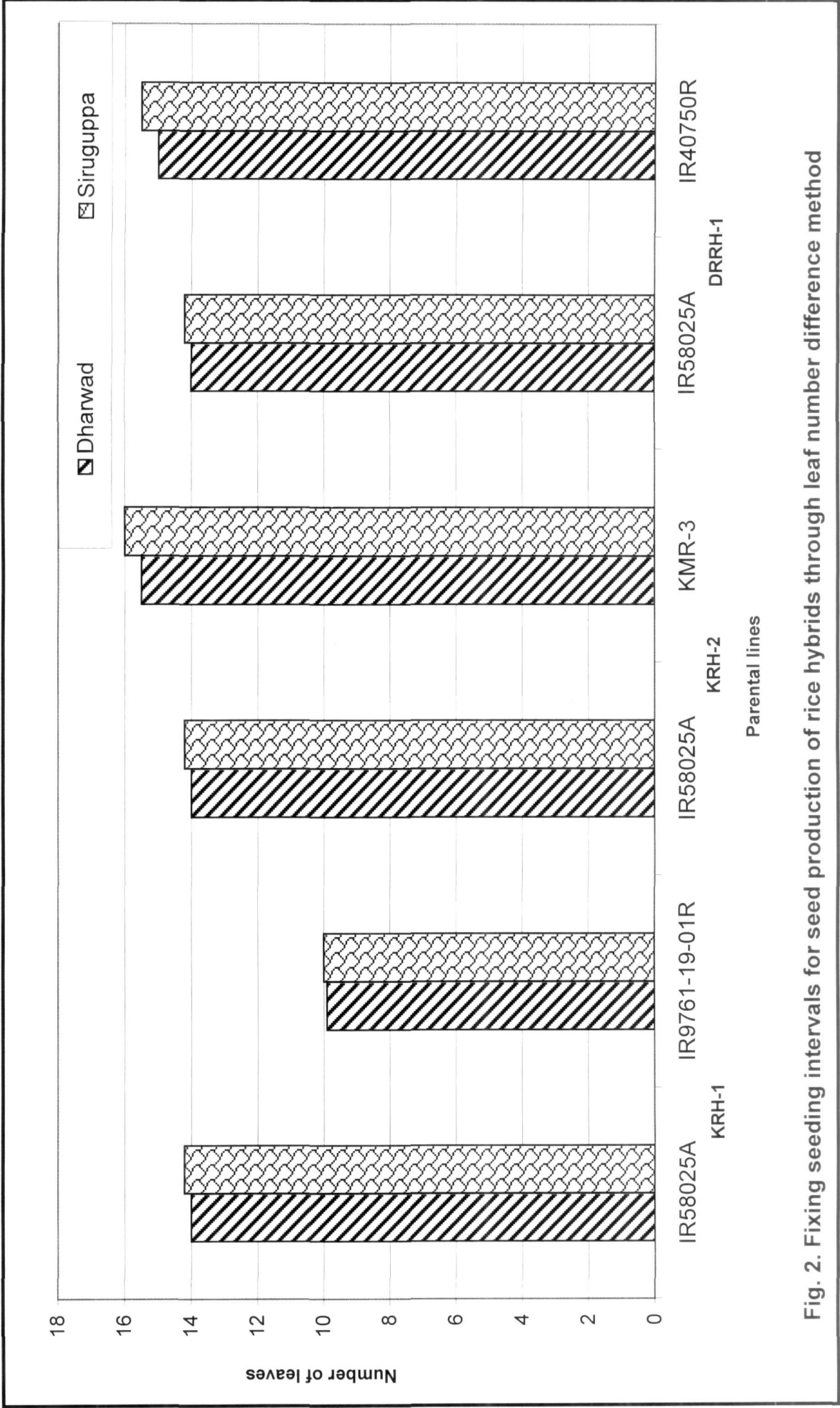


Fig. 2. Fixing seeding intervals for seed production of rice hybrids through leaf number difference method

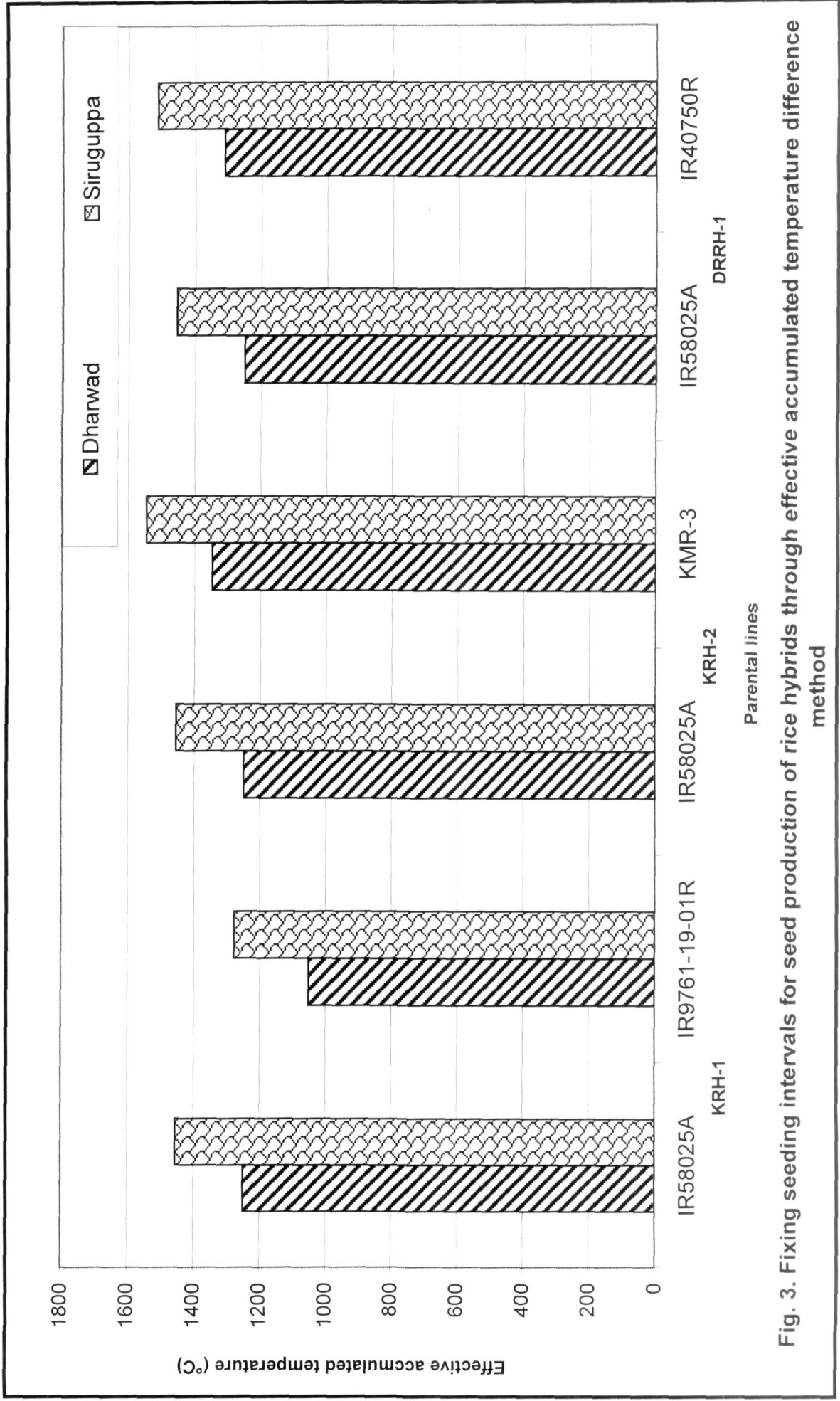


Fig. 3. Fixing seeding intervals for seed production of rice hybrids through effective accumulated temperature difference

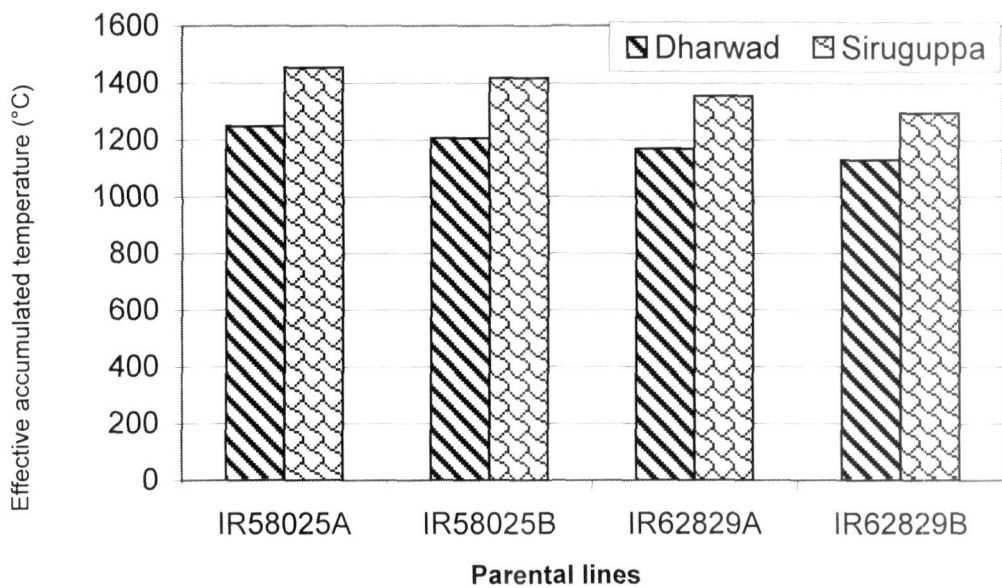
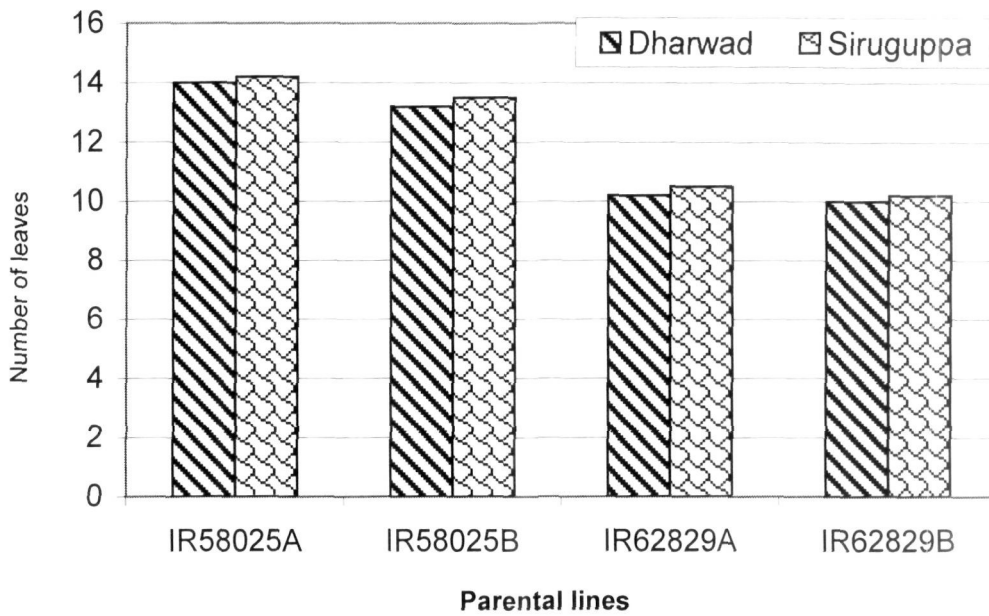
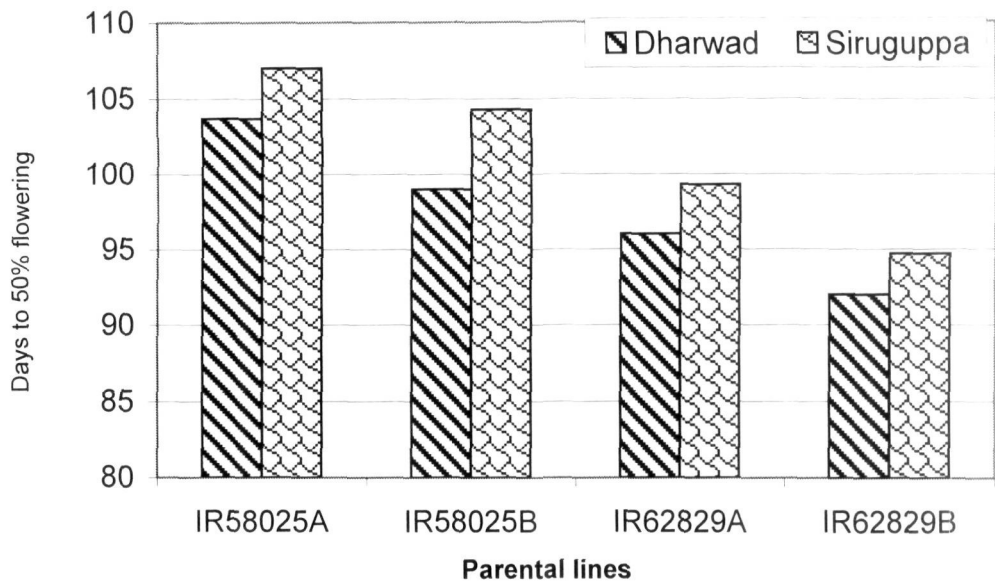


Fig. 4. Fixing seeding intervals for CMS line multiplication through GDD, LND and EAT difference methods

The leaf number differed significantly with location of production. The average number of leaves produced was higher at Siruguppa (12.8) than at Dharwad (12.5).

The interaction effect due to parental lines and locations were non-significant.

4.1.2.3 Effective accumulated temperature (EAT)

The data on EAT presented in the Table 5 (Fig. 3 and 4), reveals significant influence of parental lines and locations.

All the parental lines differed significantly for their EAT requirement at both the locations. The restorer line, KMR-3 recorded significantly higher EAT (1445.3°C) over rest of the parental lines, followed by IR40750R (1410.9°C), whereas IR9761-19-01R recorded lower EAT (1169.9°C). The EAT requirement of IR58025A, IR58025B, IR62829A and IR62829B was 1351.9, 1312.8, 1262.5 and 1212.9 degree celsius, respectively.

The average EAT requirement of the parental lines was significantly higher at Siruguppa (1408.0°C) than at Dharwad (1209.2°C).

The interaction effects due to parental lines and locations were non-significant.

4.2 EXPERIMENT 2: EFFECT OF DIFFERENT TECHNIQUES ON SYNCHRONIZATION IN FLOWERING, SEED YIELD AND QUALITY OF CMS LINE IR58025A OF RICE HYBRID

The observations recorded on female parent (CMS line) are presented here.

4.2.1 Plant height (cm)

The result on plant height revealed significant influence of gibberellic acid (Table 6). Foliar spray of GA₃ (100 ppm) at panicle initiation stage recorded significantly higher plant height (74.2cm) compared to control (65.7cm). The effect of single super phosphate on plant height was non-significant.

4.2.2 Number of productive tillers per plant

The data presented in Table 6 indicate significant effect of GA₃ on number of productive tillers per plant.

The application of gibberellic acid (100 ppm) to A line at panicle initiation stage recorded significantly higher number of productive tillers per plant (13.2) over all other treatments, and the increase was to the extent of 24.5 per cent over control. The rest of the treatments were on par with control (10.6).

4.2.3 Days to initiation of flowering

The data on days to initiation of flowering reveals significant influence of various treatments (Table 7).

The female (IR58025A) and the maintainer (IR58025B) parents took 99.0 and 95.0 days, respectively for initiation of flowering (control).

Foliar spray of GA₃ (100 ppm) to female parent at panicle initiation stage recorded significantly lower number of days for initiation of

Table 6. Plant height and number of productive tillers per plant as influenced by different treatments

Treatments	Plant height (cm)	Number of productive tillers per plant
T ₁ – Simultaneous sowing of both parents	65.7	10.6
T ₂ – Staggered sowing of B line 3 days later	65.8	10.8
T ₃ – Staggered sowing of B line 5 days later	65.6	10.7
T ₄ - T ₁ + 2.0% urea spray to B line	65.8	10.7
T ₅ - T ₁ + 100 ppm GA ₃ spray to A line	74.2	13.2
T ₆ - T ₁ + 1.0% SSP spray to A line	65.9	10.6
T ₇ – T ₁ + Jerking of B line seedlings	65.2	10.4
Mean	66.9	11.0
S.Em±	1.8	0.5
C.D. (0.05)	5.7	1.7

GA₃ - Gibberellic acid ; SSP - Single super phosphate

flowering (95.7) followed by SSP spray (96.7), compared to control (99.0) and they were on par with each other.

Staggered sowing of male parent did not influence the initiation of flowering significantly, but delayed the process marginally. Foliar spray of urea (2.0%) to B line and jerking of B line seedlings at panicle initiation stage significantly delayed the initiation of flowering by 3.0 and 2.0 days, respectively, over control.

4.2.4 Days to 50 per cent flowering

The results presented in Table 7 (Fig. 5) indicate the significant influence of various treatments on days to 50 per cent flowering.

There was a difference of 4.7 days between A and B lines for 50 per cent flowering (control).

Foliar spray of GA₃ (100 ppm) and SSP (1.0%) to female parent at initiation of panicle recorded significantly early flowering by 3.4 and 2.4 days compared to control. The number of days taken for 50 per cent flowering in these treatments was 100.3 and 101.3 days, respectively. The difference between 'A' and 'B' line for 50 per cent flowering was reduced to 1.3 and 2.3 days, respectively with these treatments.

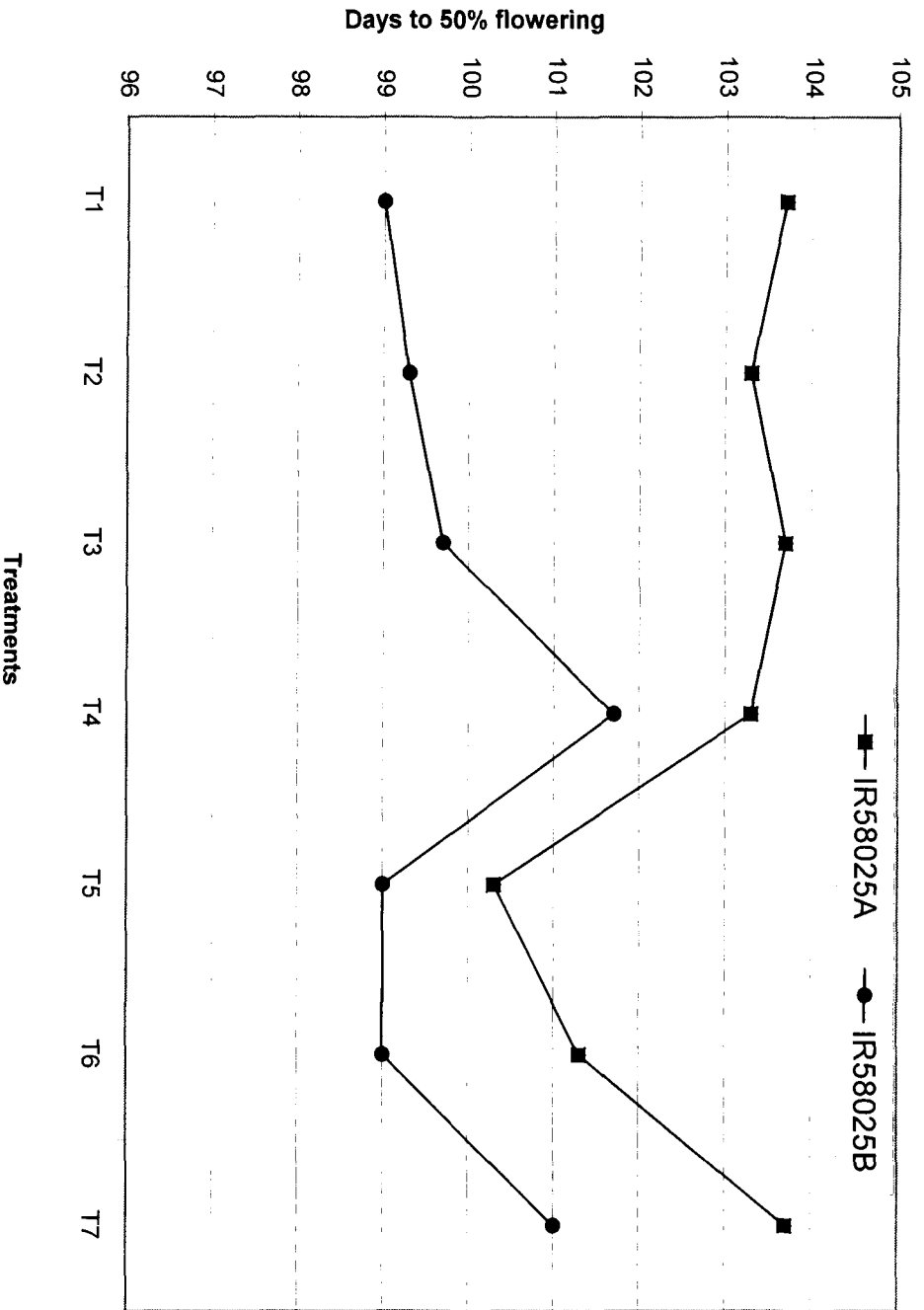
The influence of staggered sowing of male parent on days to 50 per cent flowering was non-significant. Foliar spray of urea (2.0%) and jerking the seedlings of B line at initiation of panicle significantly delayed the days to 50 per cent flowering by 2.7 and 2.0 days, respectively. These treatments were on par with each other.

Table 7. Days to initiation of flowering, days to 50 per cent flowering and days to completion of flowering in IR58025A and IR58025B as influenced by different treatments

Treatments	Days to initiation of flowering		Days to 50 per cent flowering		Days to completion of flowering		Difference in days for 50 per cent flowering (A-B)
	IR58025A	IR58025B	IR58025A	IR58025B	IR58025A	IR58025B	
	T ₁ – Simultaneous sowing of both parents	99.0	95.0	103.7	99.0	109.7	
T ₂ – Staggered sowing of B line 3 days later	99.3	95.3	103.3	99.3	109.3	105.7	4.0
T ₃ – Staggered sowing of B line 5 days later	99.3	95.7	103.7	99.7	109.7	106.0	4.0
T ₄ - T ₁ + 2.0% urea spray to B line	99.0	98.0	103.3	101.7	109.7	107.7	1.7
T ₅ - T ₁ + 100 ppm GA ₃ spray to A line	95.7	95.0	100.3	99.0	106.3	105.7	1.3
T ₆ - T ₁ + 1.0% SSP spray to A line	96.7	95.0	101.3	99.0	107.3	105.7	2.3
T ₇ – T ₁ + Jerking of B line seedlings	99.0	97.0	103.7	101.0	109.3	107.0	2.7
Mean	98.3	95.9	102.8	99.8	108.8	106.2	-
S.E.m±	0.6	0.5	0.4	0.3	0.3	0.3	
C.D. (0.05)	1.9	1.4	1.3	0.9	1.06	0.9	

GA₃ - Gibberellic acid ;

SSP - Single super phosphate



T1 - Simultaneous sowing of both parents
 T2 - Staggered sowing of B line 3 days later
 T3 - Staggered sowing of B line 5 days later
 T4 - T1 + 2.0% urea spray to B line
 T5 - T1 + 100 ppm GA3 spray to A line
 T6 - T1 + 1.0% SSP spray to A line
 T7 - T1 + Jerking of B line seedlings

Fig. 5. Days to 50 per cent flowering in IR58025A and IR58025B as influenced by different treatments

4.2.5 Days to completion of flowerings

The results presented to Table 7 indicate significant influence of various treatments on days to completion of flowering.

Foliar spray of 100 ppm GA₃ (T₅) and 1.0 per cent SSP (T₆) to A line at initiation of panicle, significantly enhanced the days to completion of flowering over control. The earliness in days to completion of flowering was higher with T₅ (3.3) followed by T₆ (2.0) which were on par with each other.

The influence of staggered sowing of male parent on completion of flowering was non-significant. Foliar spray of urea (2.0%) and jerking of B line seedlings at panicle initiation stage significantly delayed the completion of flowering by 2.0 and 1.3 days, respectively, over control, which were on par with each other.

4.2.6 Number of filled spikelets per panicle

The data on number of filled spikelets per panicle indicate significant influence of various treatments (Table 8).

All the treatments significantly increased the number of filled spikelets per panicle over control.

Foliar spray of 100 ppm GA₃ (T₅) to female parent recorded significantly higher number of filled spikelets per panicle over other chemical sprays. The number of filled spikelets per panicle was

Table 8. Number of filled spikelets per panicle, seed set percentage and seed yield per plant as influenced by different treatments

Treatment details	Number of Filled spikelets per panicle	Seed set percentage	Seed yield (g/plant)
T ₁ – Simultaneous sowing of both parents	20.0	12.8	1.6
T ₂ – Staggered sowing of B line 3 days later	27.3	18.1	2.3
T ₃ – Staggered sowing of B line 5 days later	32.0	21.9	2.9
T ₄ - T ₁ + 2.0% urea spray to B line	26.9	17.3	2.2
T ₅ - T ₁ + 100 ppm GA ₃ spray to A line	39.2	24.9	3.1
T ₆ - T ₁ + 1.0% SSP spray to A line	25.8	16.9	2.3
T ₇ – T ₁ + Jerking of B line seedlings	24.3	16.1	2.0
Mean	27.9	18.3	2.3
S.E.m±	1.4	1.1	0.1
C.D. (0.05)	4.3	3.4	0.4

GA₃ - Gibberellic acid ; SSP - Single super phosphate

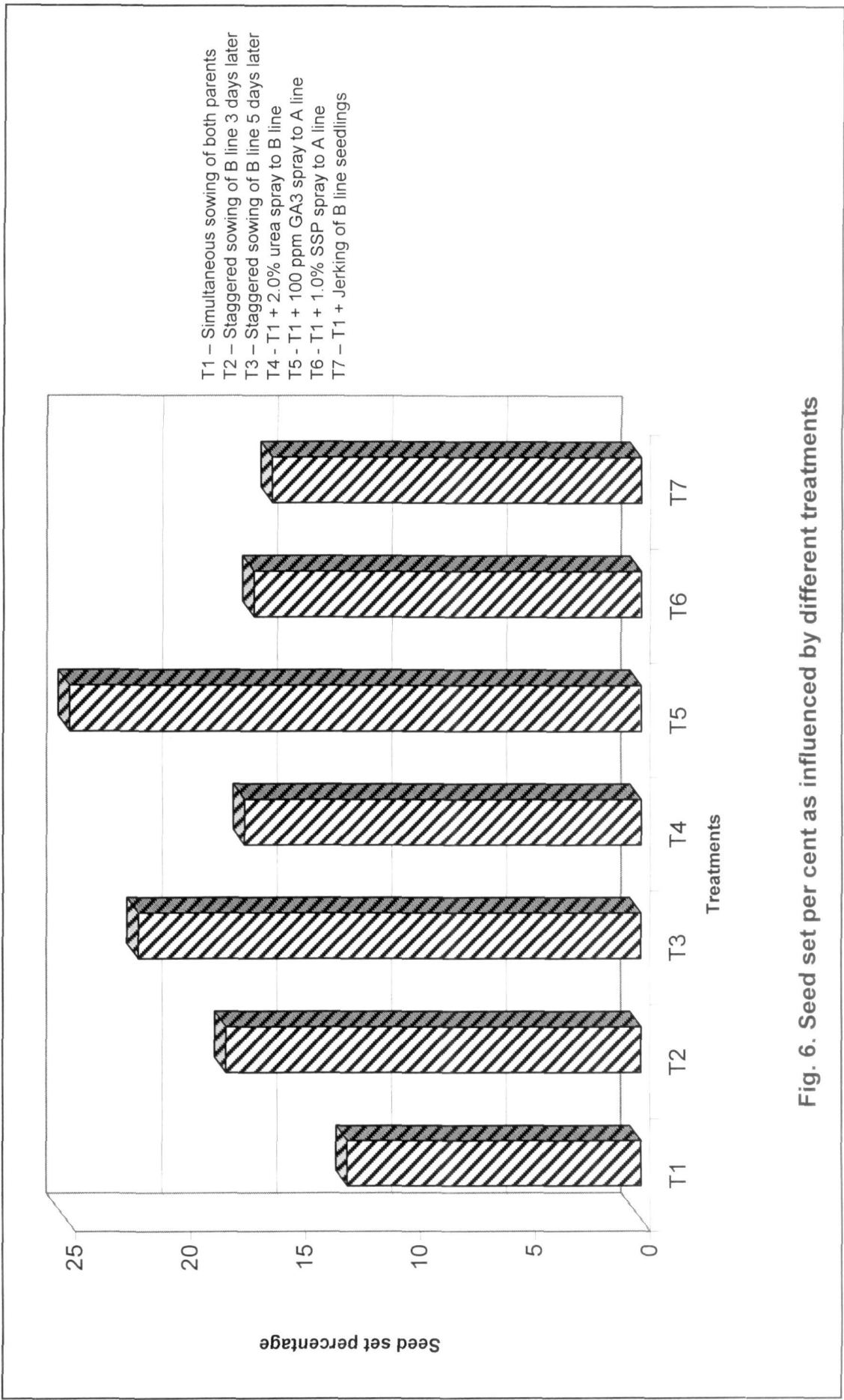


Fig. 6. Seed set per cent as influenced by different treatments

significantly higher with T₅ (39.2) compare to 1.0 per cent SSP sprays (25.8).

Staggered sowing of B line early either by three (T₂) or by five days (T₃) significantly increased the number of filled spikelets per panicle. The treatment T₃ has recorded significantly higher number of filled spikelets per panicle (32.0) compared to T₂ (27.3). Foliar spray of urea (2.0%) or jerking of male line seedlings at panicle initiation recorded significantly higher filled spikelets of 26.9 and 24.3 per panicle, respectively compared to control (20.0).

The treatments T₂, T₄, T₆ and T₇ were on par with each other for number of filled spikelets per panicle. The per cent increase in number of filled spikelets per panicle with T₅, T₃ and T₄ was 96.0, 60.0 and 34.5 per cent, respectively, over control.

4.2.7 Seed set percentage

The data on seed set percentage presented in Table 8 (Fig. 6) reveals significant influence of various treatments.

The seed set percentage significantly increased with all the treatments over control.

Foliar spray of 100 ppm GA₃ (T₅) recorded significantly higher percentage of seed setting (24.9%), over other treatments followed by staggered sowing of B line five days later (21.9%), which were on par with each other. Staggered sowing of male parent by three days (18.1%), foliar

spray of two per cent urea to male line (17.3%), one per cent SSP to female (16.9%) and jerking of B line seedlings (16.1%) at panicle initiation stage recorded seed set per cent on par with each other. The increase in seed set percentage with T₅, T₃, T₂ and T₄ was 94.5, 71.0, 41.4 and 35.2 per cent, respectively, over control.

4.2.8 Seed yield per plant (g)

Seed yield per plant was significantly influenced by various treatments (Table 8).

All the treatments were significantly superior in seed yield per plant compared to control. Foliar spray of GA₃ (100 ppm) to female parent recorded significantly higher seed yield per plant (3.1g) followed by staggered sowing of male parent by five days later (2.9g) which were on par with each other. Foliar spray of SSP (1.0%) to female parent, staggered sowing of male by three days later, two per cent urea spray to male parent and jerking of male line recorded seed yield of 2.3, 2.3, 2.2 and 2.0 grams per plant and were on par with each other.

4.2.9 Seed yield per ha (kgs)

The data on seed yield per ha revealed significant influence of various treatments (Table 9 and Fig. 7).

All the treatments were significantly superior in seed yield per hectare compared to control. Foliar application of 100 ppm GA₃ to female parent recorded significantly higher seed yield per ha (796.5 kg) followed

Table 9. Seed yield, seed recovery percentage and test weight as influenced by different treatments

Treatments	Seed yield (kg/ha)	Per cent increase over control	Seed recovery (%)	Test weight (g)
T ₁ – Simultaneous sowing of both parents	545.2	-	92.1	21.2
T ₂ – Staggered sowing of B line 3 days later	713.3	30.8	93.7	21.4
T ₃ – Staggered sowing of B line 5 days later	792.0	45.3	94.2	21.7
T ₄ - T ₁ + 2.0% urea spray to B line	713.3	30.8	93.2	21.3
T ₅ - T ₁ + 100 ppm GA ₃ spray to A line	796.5	46.1	95.8	22.1
T ₆ - T ₁ + 1.0% SSP spray to A line	705.5	29.4	93.5	21.5
T ₇ – T ₁ + Jerking of B line seedlings	694.8	27.4	93.2	21.3
Mean	708.6	-	93.7	21.5
S.E.m±	25.2		2.4	1.1
C.D. (0.05)	77.6		NS	NS

NS - Non significant;

GA₃ - Gibberellic acid;

SSP - Single super phosphate

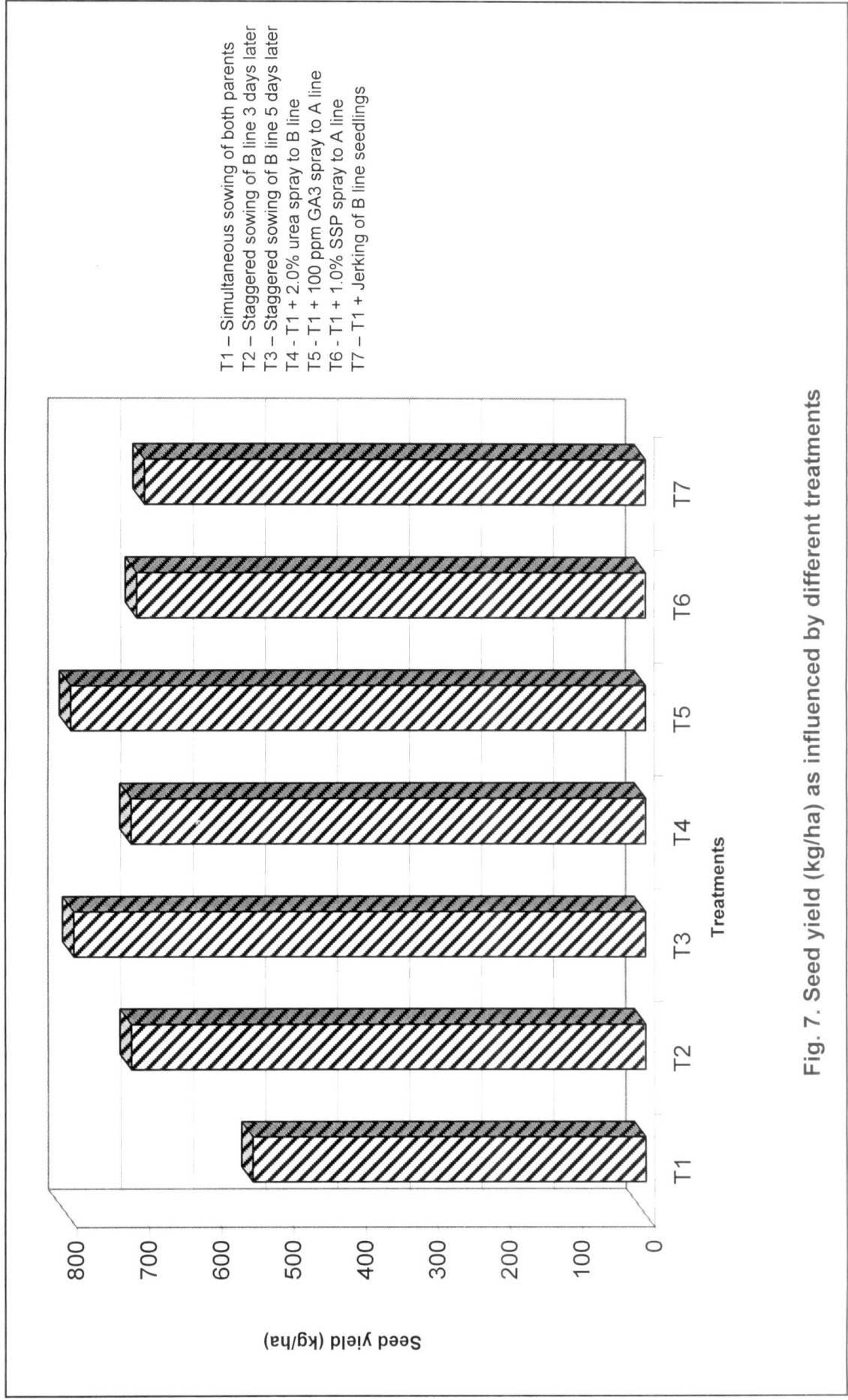
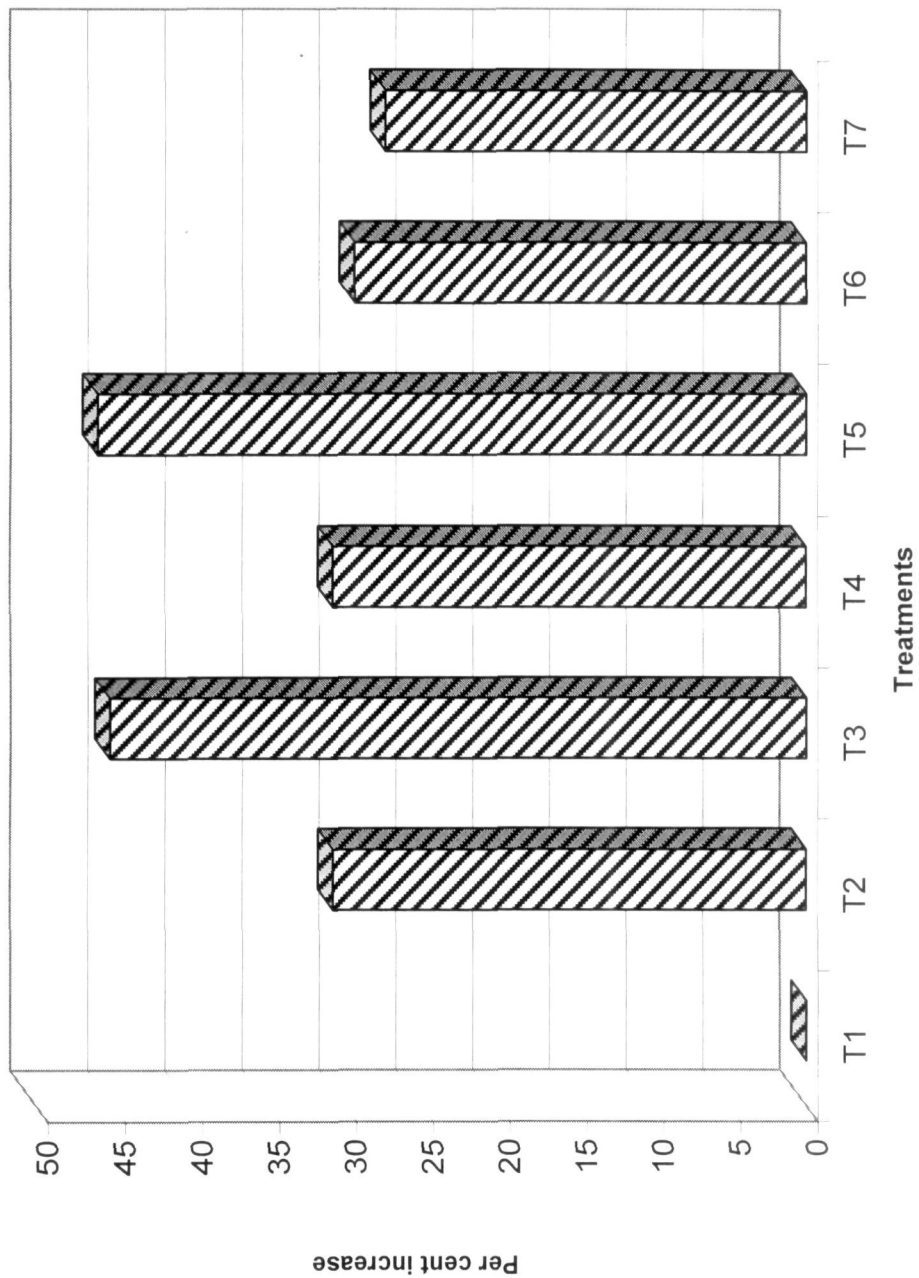


Fig. 7. Seed yield (kg/ha) as influenced by different treatments



- T1 – Simultaneous sowing of both parents
- T2 – Staggered sowing of B line 3 days later
- T3 – Staggered sowing of B line 5 days later
- T4 - T1 + 2.0% urea spray to B line
- T5 - T1 + 100 ppm GA3 spray to A line
- T6 - T1 + 1.0% SSP spray to A line
- T7 – T1 + Jerking of B line seedlings

Fig. 8. Per cent increase in seed yield (kg/ha) over control as influenced by different treatments

by staggered sowing of male parent five days later (792 kg), which were on par with each other. The per cent increase in seed yield with these treatments was 46.1 and 45.3, respectively, over control. Foliar spray of SSP (1.0%) to CMS line, urea (2.0%) to B line, staggered sowing of male line three days later and jerking of male line seedlings were on par with each other for seed yield (kg/ha) and recorded an increased seed yield of 29.4, 30.8, 30.8, 27.4 per cent, respectively, over control (Fig. 8).

4.2.10 Seed recovery percentage

The seed recovery percentage did not differ significantly among the treatments (Table 9). However, foliar application of 100 ppm gibberellic acid to female parent at panicle initiation stage recorded higher seed recovery (95.8) and the lowest seed recovery was observed with control (92.1).

4.2.11 Test weight (g)

The test weight did not differ significantly among the treatments (Table 9). However, spraying of GA₃ (100 ppm) to A line at panicle initiation stage recorded the higher test weight (22.1 g) and the seeds obtained from control recorded the lowest test weight (21.2 g).

4.2.12 Seed quality parameters

The data on seed quality parameters are presented in Table 10.

4.2.12.1 Germination percentage

The seed germination was significantly influenced by application of GA₃. The seeds obtained from the treatment receiving foliar spray of GA₃

Table 10. Germination percentage, shoot length, root length, dry weight of seedlings and vigour index as influenced by different treatments

Treatments	Germination (%)	Shoot length (cm)	Root length (cm)	Dry weight of 10 seedlings (mg)	Vigour index
T ₁ – Simultaneous sowing of both parents	90.7 (72.22)	11.1	11.2	131.3	2008
T ₂ – Staggered sowing of B line 3 days later	91.1 (72.57)	11.2	11.1	131.9	2061
T ₃ – Staggered sowing of B line 5 days later	91.5 (73.05)	11.9	11.9	132.0	2174
T ₄ - T ₁ + 2.0% urea spray to B line	91.3 (72.88)	11.4	11.5	131.9	2066
T ₅ - T ₁ + 100 ppm GA ₃ spray to A line	93.3 (75.04)	12.6	12.7	134.6	2356
T ₆ - T ₁ + 1.0% SSP spray to A line	91.7 (73.25)	11.7	11.6	131.9	2098
T ₇ – T ₁ + Jerking of B line seedlings	91.3 (72.88)	11.3	11.3	131.7	2056
Mean	91.5 (73.12)	11.6	11.6	132.2	2117
S.E.m±	0.47	0.1	0.1	0.4	21.0
C.D. (0.05)	1.5	0.4	0.4	1.1	64.0

Note: Figures in parenthesis are arcsine transformed values , GA₃ - Gibberellic acid ; SSP - Single super phosphate

(100 ppm) to female parent at panicle initiation stage recorded significantly higher seed germination (93.3%) over rest of the treatments. The lowest seed germination was observed with control (90.7). Though, the other treatments recorded higher seed germination over control, but the effect was non-significant.

4.2.12.2 Shoot length (cm)

The data on shoot length revealed significant influence of various treatments. The seeds obtained from the treatments receiving GA₃ spray recorded significantly higher shoot length (12.6cm) over all other treatments. The treatments with staggered sowing of B line five days later and foliar spray of one per cent SSP to female parent also recorded significantly higher shoot length of 11.9 and 11.7 centimeters over control (11.1 cm).

4.2.12.3 Root length (cm)

The results on root length indicated significant effect of various treatments. The seed obtained from the treatments receiving GA₃ spray recorded significantly higher root length (12.7 cm) over all other treatments. The treatments of staggered sowing of B line five days later and foliar spray of one per cent SSP to female parent also recorded significantly higher root length of 11.9 and 11.6 centimeters over control (11.2 cm).

4.2.12.4 Dry weight of seedlings (mg)

The results on dry weight of seedlings indicated significant influence of gibberellic acid application.

Significantly higher dry weight of seedlings was recorded with the treatment receiving 100 ppm GA₃ spray (134.6 mg). The rest of the treatments were on par with control (131.3 mg).

4.2.12.5 Vigour index

The data on vigour index revealed significant influence of various treatments. Significantly higher seedling vigour index was observed with the seeds obtained from the treatment receiving GA₃ (100 ppm) spray (2356). The seeds obtained from treatments T₃ (2174) and T₆ (2098) also increased vigour index significantly over control (2008). The rest of the treatments were on par with the control.

Discussion

V. DISCUSSION

Hybrid seed production utilizing cytoplasmic genic male sterility involves maintenance of CMS line and utilization of the same in F_1 seed production. Fluctuations in the expression of physiological and agronomical characters of rice plants are always observed with the change of growing environment. Such expressions are more pronounced in CMS lines. Production of hybrid seed and the maintenance of CMS lines involves crossing of two different parents, which is possible only when they flower simultaneously. Marked differences in flower synchronization were observed between CMS lines and their corresponding maintainers and in commercial F_1 seed production. The maintenance of cytosterile lines is practiced involving their isogenic lines (B). They often may or may not have same duration for flowering under a particular condition. Therefore, it becomes obligatory to adjust the seeding dates of the parents for obtaining a simultaneous flowering based on the earlier knowledge on their flowering behaviour. Thus, information on days to flowering of different parental lines is necessary. In this background, the present study was carried to study the synchronization in parental lines of rice hybrids. The results obtained are discussed in this chapter.

5.1 FIXING SEEDING INTERVALS THROUGH GROWTH DURATION DIFFERENCE (GDD), LEAF NUMBER DIFFERENCE (LND) AND EFFECTIVE ACCUMULATED TEMPERATURE DIFFERENCE (EAT) METHODS

The parental lines of most of the hybrid combinations differ in their growth duration. Precise information on growth duration of parental lines

should be known in the areas of seed production. This is most essential to adjust seeding interval (staggered sowing) between male and female parents. The growth duration of the parental lines is influenced by environmental conditions. Therefore, it is essential to know the flowering behaviour of parental lines at different locations and seasons. In rice, two other methods *viz.*, LND and EAT are suggested to find out the suitable seeding interval. The difference in leaf number of parents and EAT requirement by the parents from seeding to 50 per cent flowering will be worked out and this information will be made use to adjust the sowing dates of the parents.

5.1.1 Evaluation of parental lines

5.1.1.1 For growth and floral traits

Plant height is an important character while selecting the male and female parents in hybrid seed production programme of rice. In the process of flowering, the pollen grains after dehiscence from anther are known to move in the air current in a zigzag manner and they will settle down gradually to facilitate the pollen deposition on the stigma of female parent. It is therefore necessary that the plant height of the male parent should be higher than that of female line (Mallaiah, 1985). In the present study, considerable variation for plant height was observed ranging from 63.2 cm (IR40750R) to 110.1 cm (KMR-3). All the three restorer lines studied, were having the plant height higher than their respective CMS lines (Table 3). The variation in plant height was due to genetic character of the parental lines. Similar variation in plant height in parental lines of

rice hybrids has been observed by Jagadeesha (1997), Halaswamy *et al.* (1997b) and Biradarpatil (1999).

The angle of glume opening is one of the important floral traits, which influence the outcrossing rate. The wider the angle, higher will be the outcrossing. In the present study, the variation in angle of glume opening was observed between the parents. It was higher with restorer line KMR-3 (23.2°) and was lower with maintainer line IR58025B (21.2°). Among the two CMS lines, IR62829A (22.1°) was having wider angle of glume opening than IR58025A (21.6°). Similar variation in angle of glume opening between the rice parental lines has been observed by Patil (1983) and Jagadeesha (1997). The angle of glume opening depends on the protrusion of the anthers. Simultaneous protrusion of anther at the faster rate, widens the angle (Copeland, 1924; Kato and Namai, 1987).

5.1.1.2 For flowering and maturity

Number of days for panicle initiation and flowering varied with parental lines. The days for panicle initiation (75.7) and 50 per cent flowering (111.3) was higher in restorer line KMR-3. The lowest number of days for panicle initiation (54.7) and 50 per cent flowering (86.7) was observed in IR9761-19-01R. The restorer lines KMR-3 (KRH-2) and IR40750R (DRRH-1) flowered later by 7.7 and 4.7 days, respectively, where as IR9761-19-01R (KRH-1) flowered earlier by 17.0 days than the male sterile line IR58025A. The maintainer lines (IR58025B and IR62829B) flowered earlier than their respective male sterile lines

(Table 4). The variation in flowering days may be due to the genetic character of the parental lines. Similar variation in flowering duration has been observed by Viraktamath (1995) and Jagadeesha (1997).

Number of days required for maturity varied with the parental lines. The parental lines showed a wide range of duration (116.3 to 139.0) days for maturity.

5.1.2 Fixing seeding interval

In the present study number of leaves produced and EAT requirement of the parental lines from seeding to 50 per cent flowering has been compared with the growth duration difference method to fix the seeding interval.

5.1.2.1 Growth duration difference (GDD) method

The seeding interval is determined based on the difference between the parental lines for days to flowering. Among the parental lines, KMR-3 took more days for 50 per cent flowering in both the locations (113.3), while IR9761-19-01R took less number of days (90.1). Similar genotypic variation in days to 50 per cent flowering has been observed by Jagadeesha (1997) and Viraktamath *et al.* (1998) in rice.

Significant influence of location on flowering of the parental lines was observed. At Siruguppa, all the lines took more number of days to 50 per cent flowering compared to Dharwad (Table 5 and Fig. 1 and 4). Similar variation in flowering of the parental lines at different locations

has also been observed by Biradarpatil (1999). The variation in flowering between the location may be due to influence of varied range of temperature at each locations. The maximum temperature at Siruguppa was high and ranged between 22.9°C to 38.2°C compared to Dharwad (16.9°C to 30.4°C). Jagadeesha (1997) observed late flowering of the parental lines during summer where in the temperature range was higher compared to *kharif*.

In the present study, a growth duration difference of 3.7 and 4.0 days between IR58025A/B and IR62829A/B, respectively was observed. The restorer lines of KRH-2 (KMR-3) and DRRH-1 (IR40750R) flowered 8.0 and 5.0 days later than the male sterile line (IR58025A), respectively, where as, the an other restorer line (IR9761-19 -1R) of KRH-1 rice hybrid flowered 15.2 days earlier than the CMS line IR58025A.

5.1.2.2 Leaf number difference (LND) method

Unlike growth duration, the number of leaves of a given genotype is found to be relatively stable over the seasons and locations, and hence, this criteria can be used to determine seeding interval between parental lines more accurately (Viraktamath, 1995; Jagadeesha, 1997). Leaf number method is considered more reliable since this method to based on physiological growth and age of the plant (Anon., 1995a) In the present study, the restorer line KMR-3 produced more number of leaves (15.7), where as another restorer line (IR9761-19-01R) produced less number of leaves (9.9) for days to 50 per cent flowering compared to other parental

lines. The parental lines IR58025A, IR58025B, IR62829A, IR62829B and IR40750R recorded 14.1, 13.3, 10.3, 10.1 and 15.2 leaves respectively, for days to 50 per cent flowering (Table 5 and Fig. 2 and 4). The number of leaves produced by each genotype is mainly the genetically determined phenomenon (Jagadeesha, 1997; Viraktamath *et al.*, 1998).

The parental lines grown at Siruguppa and Dharwad did not differ much for number of leaves produced upto 50 per cent flowering.

Based on leaf number difference of the parental lines the seeding interval could be determined. For taking up of seed production of KRH-2 and DRRH-1 the male sterile line (IR58025A) of these hybrids should be planted after the respective restorer lines (KMR-3 and IR40750R) attains the leaf number of 1.6 and 1.1, respectively, for achieving better synchronization between the parents. Where as, for KRH-1 seed production the restorer line (IR9761-19-01R) should be planted after the male sterile line (IR58025A) attains the leaf number of 4.2. For multiplication of CMS lines also, the seeding interval can be similarly worked out based on the difference in the leaf number. Similar recommendations of seeding interval based on leaf number difference between parents of KRH-1, KRH-2 and DRRH-1 rice hybrids has been made by Jagadeesha (1997) and Krishnamurthy *et al.* (1999)

5.1.2.3 Effective accumulated temperature difference (EAT) method

In the places where temperature changes are very frequent, or the varieties involved in hybrid seed production are sensitive to temperature

the GDD method is not very much effective in determining the seeding interval, under these circumstances, the EAT method can be conveniently used. From physiological point of view, the range of temperature from 12°C to 30°C only is useful to the rice plant which influence the flowering process (Viraktamath, 1995). Every variety requires a specific quantum of temperature to reach flowering stage. The effect of accumulated temperature of a given variety remain relatively stable irrespective of time of seeding. Thus, seeding interval can be worked out based on the difference in EAT requirement of the parental lines. In the present study, on an average KMR-3 took maximum EAT (1445.3°C), while IR9761-19-01R took less EAT (1639.°C) from sowing to 50 per cent flowering (Table 5 and Fig. 3 and 4). The variation in EAT requirement of the parental lines is a genetic character. Similar variation in EAT requirement of the parental lines has been observed by Jagadeesha (1997) and Anon (1999b).

All the parental lines took more EAT at Siruguppa compared to Dharwad condition. This may be due to high daily average temperature that ranged between 22.9°C to 38.2°C at Siruguppa compared to at Dharwad (16.9°C to 30.4°C). High fluctuating temperature obstructs the initial flowering because, every variety requires a specific quantum of temperature to reach flowering stage (Jagadeesha, 1997).

Based on difference in EAT requirement of the parental lines at particular location and season, the seeding interval can be recommended. In the present study, the EAT difference was 42.0°C and 35.9°C between

IR58025A/B, 198.8°C and 176.9°C between IR58025A/ IR9761-19-01R (KRH-1), 96.9°C and 90.1°C between IR58025A/KMR-3 (KRH-2) and 60.7°C and 57.6°C between IR58025A/IR40750R (DRRH-1) at Dharwad and Siruguppa, respectively.

Among the three methods used for determining seeding intervals the leaf number difference method was found to be more reliable. The number of leaves produce was relatively stable at both the locations. The growth duration of the parental lines and EAT requirement by the parental lines varied with locations due to the changed environmental conditions.

5.2 EFFECT OF DIFFERENT TECHNIQUES ON SYNCHRONIZATION IN FLOWERING, SEED YIELD AND QUALITY OF CMS LINE IR58025A OF RICE HYBRID

Synchronization of flowering between parental lines assumes greater significance as the seed set on female parent depends on the pollen supplied from male parent (maintainer) during flowering period. Failure to obtain proper synchronization between the CMS and maintainer line is one of the main problems in CMS line multiplication, resulting in very poor seed set. In spite of adjusting the sowing dates, the problem of non-synchrony in flowering of parental lines will be observed because of the differential response of the parents to the change in environmental conditions at different locations and seasons. Therefore, it is essential to adjust the flowering of parental lines after observing the

difference at primordial development stage. If the difference in flowering is marginal (1-5 days), it can be manipulated through additional application of nitrogen, phosphorus, growth regulators like gibberellic acid and jerking of the seedlings. In the present study, these techniques are utilized to adjust the flowering between the parents during CMS line (IR58025A) seed production.

5.2.1 Effect of staggered planting

If the difference in flowering between the two parents is more than marginal, the only alternative to achieve synchrony in flowering is staggered sowing of male parent (maintainer). This has been in practice since the release of hybrids. Since, the standardization of staggered sowing is a basic need for further seed production technology, an attempt was made to find out the suitable sowing dates of maintainer and CMS line for achieving better synchrony in flowering.

The maintainer line (IR58025B) was early in 50 per cent flowering by 4.7 days than the CMS line (control). The variation in flowering days in parental lines may be attributed to the genetic characters of the parents. Similar variation in flowering behaviour of the CMS and maintainer lines of rice hybrids has been reported by Jagadeesha (1997), Krishnamurthy and Nagalikar (1999) and Biradarpatil (1999).

The staggered sowing of maintainer line three and five days later did not influence the days to flowering significantly, and reduced the difference in days to 50 per cent flowering between the two parent to 1.4

and 0.9 days, respectively. The late sowing of maintainer line by five days resulted in better synchronization in flowering between the parents. Similar observation on staggered sowing in CMS line multiplication has been reported by Rangasamy and Sreerangasamy (1988) and Krishnamurthy and Nagalika (1999).

Staggered sowing of maintainer line significantly increased the seed set on female parent and thus resulted in higher seed yield. This was due to better synchronization in flowering. Sowing of male parent by five days later, resulted in higher seed set (21.9%) and seed yield (792 kg/ha) of CMS line (Table 9 and Fig. 5). Increase in seed yield with late sowing of maintainer line by three and five days was 30.8 and 45.3 per cent, respectively, over control. The higher seed set with these treatments was due to better outcrossing rate leading to higher number of filled spikelets per panicle. Similar observations have also been reported earlier by Megachandrasingh (1986), Halaswamy *et al.* (1997a) and Jagadeesha (1997).

5.2.2 Effect of gibberellic acid

5.2.2.1 Effect on flowering

Gibberellic acid (GA₃) being a growth regulator, is known to enhance the growth and flowering. In the present investigation, it is used to hasten the flowering of female parent. Foliar spray of 100 ppm GA₃ to female parent at panicle initiation enhanced the 50 per cent flowering by 3.4 days. These results are in accordance with findings of Halaswamy *et*

al. (1997b), Lingaraju *et al.* (1998), Biradarpatil (1999) and Yogeasha *et al.* (2000) in parents of hybrid rice.

The probable reason for the early flowering with GA₃ spray may be due to the induction of this chemical towards higher total dry matter production at early stages of growth, which might have been more conducive for flowering (Malali, 1979). Further, the applied gibberellic acid might have decisively increased the level of endogenous gibberellins and helped the flower initiation as reported by Nichols and May (1964). Krishnamoorthy (1975) also stated that gibberellic acid acts directly on growing bud and convert vegetative phase into reproductive one. The flower forming hormone florigen is supposed to contain gibberellins and anthesins and thus, exogenous application of GA₃ might have regulated this balance of gibberellins and anthesins and resulted in early flowering (Joshi, 1976).

5.2.2.2 Effect on growth and seed yield

The gibberellic acid had a favourable effect on growth and yield parameters. Foliar spray of GA₃ (100 ppm) to female parent increased the plant height and number of number of productive tillers per plant significantly, over other treatments. The increase in plant height might be due to triggering of metabolic activity involved in cell division and cell elongation. The effect of GA₃ on plant height was in accordance with the reports of Duan and Ma (1992) and Bong *et al.* (1994) in rice. Increase in number of productive tillers per plant may be due to increased metabolic activity and in turn enhanced vegetative growth. These result are in

accordance with the findings Xu and Li (1988), Jagadeeshwari *et al.* (1998) and Biradarpatil (1999) who observed higher number of productive tillers per plant due to GA₃ spray.

Significant increase in seed yield of CMS line was observed with the application of GA₃. The foliar spray of GA₃ (100 ppm) to female parent at panicle initiation recorded 46.1 per cent higher seed yield over control. The increase in seed yield with GA₃ was mainly due to increased seed set per cent because of better outcrossing rate. The seed set percentage increased by 94.5 per cent, over control. Better synchronization in flowering between the parents with the application of GA₃ due to reduced difference in days to flowering, resulted in increased number of filled spikelets per panicle by 96.0 per cent, over control. Similar results were also reported by Halaswamy *et al.* (1997b) and Biradarpatil (1999) in KRH-2 hybrid rice seed production.

The other reasons for increased seed yield with GA₃ spray might be due to increased panicle exertion, wider opening of the florets and increased flag leaf angle, which might have resulted in higher outcrossing rate (Yuan and Virmani, 1988; Virmani *et al.*, 1991). The GA₃ might have facilitated better translocation of metabolites from source to sink resulting in higher number of filled spikelets per panicle (Kaur and Singh, 1986).

5.2.2.3 Effect on seed quality

The foliar spray of GA₃ (100 ppm) recorded significantly higher seed quality parameters over rest of the treatments. The seeds obtained from the treatment receiving GA₃ spray recorded 2.8, 17.3 and 2.5 per cent

higher seed germination, vigour index and dry weight of seedlings, respectively, over control (Table 10). The increase in seed quality with GA₃ might be due to increased test weight and better filled seeds because of better transaction of metabolites from source to sink. This is in accordance with the findings of Deshpande (1993), Revanasiddappa (1996) and Biradarpatil (1999) in rice.

5.2.3 Effect of phosphorus

5.2.3.1 Effect on flowering

In the present investigation, the foliar spray of one per cent single super phosphate to female parent at panicle initiation enhanced the 50 per cent flowering by 2.4 days. Similar effect of phosphorus in enhancing the flowering in rice was also observed by Venkataraman and Raja (1971), Kailasam *et al.* (1978), Halaswamy *et al.* (1997b) and Biradarpatil (1999).

The early flowering with foliar spray of phosphorus might be due to early induction of reproductive phase (Saleem *et al.*, 1989; Halaswamy *et al.*, 1997b). The phosphorus application increases Bartlett's index of flowering and there by results in early flowering (Venkataraman and Raja, 1971).

5.2.3.2 Effect on growth, seed yield and seed quality

Foliar spray of one per cent single super phosphate to female parent at panicle initiation did not influence the plant height and productive tillers per plant significantly, but increased these parameters

marginally, over control. Significant increase in seed yield and yield parameters was observed with the spray of SSP. The foliar spray of SSP increased the seed yield of female parent by 29.4 per cent, over control. This was due to better synchrony in flowering between the parents, which resulted in higher outcrossing and thus increased number of filled spikelets per panicle. The seed set percentage increased by 32.0 per cent, over control. Similar beneficial effect of phosphorus in increasing the seed yield of hybrid rice has been reported by Halaswamy *et al.* (1997b) and Biradarpatil (1999).

Though, the phosphorus spray recorded higher values for seed quality parameters compared to control, but its effect was non-significant.

5.2.4 Effect of nitrogen

In the present investigation, the foliar spray of urea (2.0%) to male parent at initiation of panicle delayed the 50 per cent flowering by 2.7 days and resulted in only 1.6 days difference in flowering between the parents. As the rice is believed to be the nitro negative crop, the foliar spray of urea might have prolonged the vegetative growth and thus resulted in delayed flowering of male parent. Similar effect of urea spray on the flowering of parental lines of rice has been reported by Halaswamy *et al.* (1997b), Lingaraju *et al.* (1998) and Biradarpatil (1999)

Significant increase in seed set and seed yield was observed with the foliar spray of urea (2.0%). The seed set and seed yield per ha increased by 35.2 and 30.8 per cent, respectively, over control. Better

synchrony in flowering with the urea spray resulted in higher outcrossing rate and thus increased the number of filled spikelets per panicle. As a result of this, the seed set and the seed yield increased. This is in accordance with findings of Halaswamy *et al.* (1997b) and Biradarapatil (1999) in KRH-2 hybrid rice seed production.

5.2.5 Effect of jerking

In the present investigation, jerking of B line seedlings at panicle initiation stage delayed the 50 per cent flowering by two days and thus resulted in reduced difference in flowering between the parents (Table 7). The delayed flowering due to jerking was mainly because of the shocks the seedlings received upon disturbing the roots. The roots of disturbed seedlings needs time for recovery and further establish and grow in the field, and thus delaying the growth processes. These results are in accordance with the findings of Nguyan *et al.* (1998) and Halasawamy *et al.* (1997b) who advocated disturbing of roots by cutting or by retransplanting of seedlings to delay the flowering of early parent in hybrid rice seed production. Agrawal (1998) also recommended jerking of early flowering plants to delay the flowering in hybrid seed production of pearl millet.

The jerking of maintainer line seedlings significantly increased the seed yield by 27.4 per cent, over control. The increased seed yield with this treatment was due to increased seed set percentage because of better outcrossing. The reduced difference in days to flowering between the

parents resulted in higher outcrossing rate and thus enhanced the seed set percentage.

Practical application of results

Based on the results of the investigation carried out during the course of study, the following recommendations can be made.

1. For Seed production of KRH-2 and DRRH-1 staggered sowing of male line 7-8 and 4-5 days early at Dharwad and 8.0 and 5.0 days early at Siruguppa could be practiced, where as for seed production of KRH-1 late sowing of male parent by 17.0 and 13-14 days at Dharwad and Siruguppa respectively, is useful for achieving better synchronization in flowering.
2. The leaf number difference method and EAT methods can be utilized for fixing the seeding interval between the parents of KRH-1, KRH-2, DRRH-1 and IR58025A/B based on the difference in leaf number and EAT.
3. Staggered sowing of male parent by five days later than female parent can be practiced in CMS line (IR58025A) multiplication for getting better synchronization in flowering between the parents.
4. To delay the early flowering parent, foliar spraying of urea (2.0%) and jerking of seedlings at panicle initiation can be practiced in hybrid seed production or CMS line multiplication.
5. Similarly, to enhance the flowering of the late parent, foliar spraying of GA₃ (100 ppm) and SSP (1.0%) at panicle initiation can be practiced.

1. Studies on flowering behaviour of different parental lines of rice hybrid at different locations during different seasons can be carried out to generate the basic information on flowering behaviour of the parental lines.
2. Further studies on seeding interval of parental lines of different rice hybrids need be carried out at different seasons and locations by adopting different methods like growth duration difference, leaf number difference and effective accumulated temperature difference methods.
3. Research on CMS line seed production of rice can be taken up at different locations and seasons to find out suitable location and season for getting higher seed yield with better quality.
4. Studies on staggered sowing of male parent can be carried out for each hybrid and CMS line multiplication to find out better combination of sowing dates to get perfect synchrony in flowering.
5. Further studies on use of nitrogen, phosphorus, GA₃ and other chemicals in seed production of different hybrids can be taken up for reducing the difference in flowering days of the parents.
6. Further studies on jerking of early parent at different stages of plant growth need to be carried out.

Summary

VI.SUMMARY

Maintenance of CMS lines involve crossing of two different parents, which is possible only when they flower simultaneously. Much differences in initiation of flowering and post flowering behaviour is being observed between a CMS line and its maintainer line, although they are isogenic lines. The information on flowering behaviour of the parental lines of rice hybrid is necessary to adjust the sowing dates for achieving synchronization in flowering between the parents. The GDD, LND and EAT methods can be utilized to fix the seeding interval between the parental lines of rice hybrid.

Even after adjusting the sowing dates, some time non-synchrony in flowering is observed due to the influence of environmental conditions. The flowering under such situations needs to be manipulated by additional application of nutrients, growth regulators etc. In view of this the present investigation "Synchronization studies in parental lines of rice hybrids" was carried out with two field experiments during 2000-2001 at Main Research Station, Dharwad and Agricultural Research Station, Siruguppa. The salient findings of the study are summarised here.

The parental lines evaluated for growth and flowering characters indicate lot of variation among themselves. The higher plant height (110.1 cm) and angle of glume opening was observed with KMR-3 (23.2°). There was a difference of 15.2, 8.0 and 5.0 days, respectively, for 50 per cent flowering between the restorer and male sterile lines of KRH-1, KRH-2 and

DRRH-1 rice hybrids. The male sterile and maintainer lines also differed in days to 50 per cent flowering.

Significant influence of production location on flowering days was observed in parental lines of rice hybrid. In general, the parental lines grown at Siruguppa flowered 4.3 days later than Dharwad.

The total number of leaves recorded from seeding to 50 per cent flowering was fairly stable in both the locations. The number leaves produced upto 50 per cent flowering ranged from 9.9 (IR9751-19-01R) to 15.7 (KMR-3). For taking up of seed production of KRH-2 and DRRH-1, the male sterile the (IR58025A) of these hybrids should be sown after their respective restorer lines (KMR-3 and IR40750R) attains the leaf number of 1.6 and 1.1, respectively. Where as, for KRH-1 seed production, the restorer line (IR9761-19-01R) should be planted after the male sterile line (IR58025A) attains the leaf number of 4.2.

The effective accumulated temperature requirement by the parental lines from seeding to 50 per cent flowering varied with the parental lines and locations. The parental lines KMR-3 and IR9761-19-01R took higher and lower EAT of 1445.3°C and 1169.9°C, respectively compared to other parental lines. The EAT requirement of the parental lines at Siruguppa was higher (1408.0°C) than at Dharwad (1209.2°C). The restorer lines of KRH-2 and DRRH-1 required higher EAT compared to their respective male sterile lines, where as the restorer line of KRH-1 required lesser EAT than the CMS line. The maintainer lines recorded lesser EAT compared to the male sterile lines.

In the synchronization studies, it was observed that the maintainer line (IR58025B) was early by 4.7 days in 50 per cent flowering than the male sterile line (IR58025A). The staggered sowing of maintainer line five days later found to achieve better synchronization in flowering and increased the seed yield by 45.3 per cent, over control. The staggered sowing of B line three days later increased the seed yield by 30.8 per cent, over control.

The foliar spray of GA₃ (100 ppm) and SSP (1.0%) to female parent at panicle initiation enhanced the 50 per cent flowering by 3.4 and 2.4 days and increased the seed yield of CMS line by 46.1 and 29.4 per cent, respectively over control.

Foliar spray of urea (2.0%) to maintainer line at panicle initiation delayed the 50 per cent flowering by 2.7 days and increased seed the yield by 30.8 per cent, over control. Jerking the seedlings of maintainer line at panicle initiation also delayed the 50 per cent flowering by two days and increased seed yield by 27.4 per cent, over control.

Seed quality parameters *viz.*, the seed germination, the shoot and root length, dry weight of seedlings and vigour index were significantly higher with the seeds obtained from the treatment receiving foliar spray of GA₃ (100 ppm).

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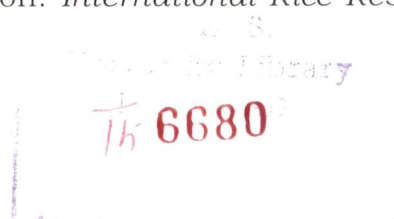
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* Originals not seen

Appendix

APPENDIX 1

Physical and chemical properties of soil samples from the experimental sites

	Particulars	Dharwad	Siruguppa
I.	Physical properties		
	Sand (%)	23.30	23.05
	Silt (%)	28.50	25.92
	Clay (%)	47.20	49.8
	CEC (me/100g)	43.00	-
II.	Chemical properties		
	Available N (kg/ha)	269.50	260.7
	Available P (kg/ha)	19.40	28.0
	Available K (kg/ha)	303.60	380.0
	pH (1:2.5)	7.80	8.5
	EC (dSm ⁻¹)	1.10	0.35



SYNCHRONIZATION STUDIES IN PARENTAL LINES OF RICE HYBRIDS

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ABSTRACT

The field experiments were carried out at Main Research Station, Dharwad and Agricultural Research Station, Siruguppa during *kharif* 2000-01 on synchronization of flowering in parental lines of rice hybrids.

Among the parental lines the restorer line KMR-3 required more effective accumulated temperature and produced more number of leaves, where as another restorer line IR9761-19-01 required less effective accumulated temperature and produced less number of leaves till 50 per cent flowering at both the locations. The maintainer line required less effective accumulated temperature and produced less number of leaves compared to their respective CMS lines. The growth duration and effective accumulated temperature requirement of the parental lines varied with locations, where as, the number of leaves produced by the parental lines was relatively stable. Hence, the leaf number difference method was found to be more reliable for adjusting the planting dates of parental lines at both the locations.

The maintainer line (IR58025B) was early by 4.7 days in 50 per cent flowering than the female line (IR58025A). Sowing of maintainer line, five days later than the female line was found to achieve better synchronization and increased the seed yield by 45.3 per cent, over simultaneous planting (control). The foliar spray of gibberellic acid (100 ppm) or single super phosphate (1.0%) to female parent at panicle initiation enhanced the 50 per cent flowering by 3.4 and 2.4 days and increased the seed yield of female line by 46.1 and 29.4 per cent, respectively over control. Foliar spray of urea (2.0%) to maintainer line or jerking the seedling of maintainer line at panicle initiation delayed 50 per cent flowering by 2.7 and 2.0 days and increased the seed yield by 30.8 and 27.4 per cent, respectively over control. Spraying of gibberellic acid 100 ppm and simultaneous planting recorded significantly higher germination (93.3%), shoot length (12.6 cm), root length (12.7 cm), seedling dry weight (134.6 mg) and vigour index (2356) compared to all other treatments.