" Affectionately
Dedicated to
My beloved parents
Who have strived
To make me
What I am ! "

-- Pradeepkumar

STIGMA RECEPTIVITY AND POLLEN VIABILITY STUDIES IN DIFFERENT PARENTAL LINES OF SORGHUM HYBRIDS

By

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B. Sc. (Agri.) First Class with Distn.

A Thesis submitted to the

MAHATMA PHULE AGRICULTURAL UNIVERSITY,

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in partial fulfilment of the requirements for the degree

of

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RAHURI 413722

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CANDIDATE'S DECLARATION

I hereby declare that this thesis or part thereof has not been submitted by me or other persons to any other University or Institute for a Degree or Diploma.

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This is to certify that the thesis entitled, " Stigma receptivity and pollen viability studies in different parental lines of sorghum hybrids", submitted to Mahatma Phule Agricultural University, Rahuri for the award of the degree of **MASTER OF SCIENCE** (Agriculture) in **SEED TECHNOLOGY**, embodies the results of a bona fide research carried out by Shri. Pradeepkumar Annasaheb Patil, under my guidance and supervision and that no part of the thesis has been submitted for any Degree or Diploma.

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CERTIFICATE

This is to certify that the thesis entitled, " Stigma receptivity and pollen viability studies in different parental lines of sorghum hybrids", submitted to the Faculty of Agriculture, Mahatma Phule Agricultural University, Rahuri, District-Ahmednagar (Maharashtra) in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE** (Agriculture) in **SEED TECHNOLOGY** embodies the results of a piece of bona fide research work carried out by **SHRI. PRADEEPKUMAR A. PATIL**, under the guidance of Dr. D.R.Bapat, Senior Sorghum Breeder, Mahatma Phule Agricultural University, Rahuri, District-Ahmednagar, and that no part of the thesis has been submitted for any other degree or publication.

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Patil

(Pradeepkumar A. Patil)

Rahuri

Dated June 1/, 1985

TABLE OF CONTENTS

TABLE OF CONTENTS

(Contd...)

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

STIGMA RECEPTIVITY AND POLLEN VIABILITY STUDIES IN DIFFERENT PARENTAL LINES OF SORGHUM HYBRIDS

By

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The present investigation entitled "Stigma receptivity and pollen viability studies in different parental lines of sorghum hybrids" was undertaken to obtain information on stigma receptivity and pollen viability in different parental lines of sorghum hybrids. The work was carried out at Mahatma Phule Agricultural University, Central Campus Rahuri. The performance of five females and five pollinator parents was studied during the course of present investigation in three seasons (kharif, rabi and summer).

Stigma receptivity studies revealed that in kharif season stigma receptivity was observed for a long period in all the male sterile lines i.e. 11 to 13 days, followed by rabi season (7 to 13 days) and in summer season stigma receptivity period was of only 5-11 days. These findings suggest that even if the male parents are sown later than female parents by 5-7 days, seed setting may not be reduced significantly. However, suitable staggered sowing of the female and male parents is necessary in different seasons to achieve synchronous flowering and good seed setting.

Pollen viability studies revealed that in kharif pollen viability period of 4 hours was observed in all the restorer lines excepting Swarna where it was 2 hours only. In rabi season 4 hrs viability period was noticed in IS-84, CS-3541, and PD 3-1-11 followed by 2 hrs in 168 and Swarna. In summer season pollens remained viable only for 2 hrs in all the restorer lines. Thereafter pollens lost their viability.

contd.....xiii/-

As regards temperature and humidity effect, it is interesting to note that early parents flower early in all the seasons, though the period required to flowering varies in different seasons. In comparison with kharif season flowering of male and femlae lines was delayed by 16 to 24 days in rabi and 2 to 9 days in summer season. Summer sowing was delayed and the crop flowered in June, which possibly reduced the flowering duration. Thus it could be seen that both male sterile and restorer lines studied showed thermosensitiveness and pattern of delayed early flowering was uniform in all the lines in different seasons.

1. INTRODUCTION

1. INTRODUCTION

Sorghum (Sorghum bicolour (L.) Moench) popularly known as jowar is the most important food and fodder crop of dry-land agriculture in India. It is a staple food for millions of people in Africa and Asia. In addition, its stalks are used as fodder and feed to animals, providing milk and meat for the nourishment of human being. Minor uses include the preparation of syrups, alcohol, alcoholic beverages, broom and basketry material from stalks.

Unlike rice and maize, sorghum can better withstand under moisture stress conditions and hence, it is predominantly grown in arid and semi-arid regions. Sorghum is considered to be of Ethiopian origin. The genus sorghum belongs to family gramineae. The sorghums are amazingly diverse group of plants probably more diverse genetically than any other crop plant. They vary tremendously in height, tillering, leaf size and number, juiciness of stalks, seed size and texture, seed coat colour, endosperm colour and size and compactness of panicle.

The annual area under this crop is 16.4 million hectares in the country. In the state of Maharashtra 6.48 million hectares are under this crop (jowar), which is 41 per cent of India's total area (1980-81). Out of this 3.0 and 3.4 million hectares are sown in kharif and rabi season, respectively. The contribution of sorghum to the total food grain production (About 100 to 105 lakh tonns) of the state

is nearly 50 per cent, indicating its pivotal role in food grain self-sufficiency of the state.

The hybrid CSH-1 was released in 1964 for general cultivation. Since then the hybrids like CSH-2, CSH-3, CSH-4, CSH-5, CSH-6, CSH-9 for kharif and CSH-7R and CSH-8R for rabi, were released for general cultivation. The coverage under hybrids in kharif increased from 20% in 1970-71 to 65 % in 1980-81, which resulted in increasing the total kharif production from 8.9 lakh tonnes to 34.4 lakh tonnes. Such trend is not observed in the rabi season mainly becuase of low coverage under hybrids and high yielding varieties which at present stands at only 3 to 5 %. For further increasing jowar production in kharif and rabi, it is necessary to bring more area under hybrids high yielding varieties. This will naturally necessiate production of sufficient quantity of certified seed. The present requirement of certified seed is about 2 lakh quintals. Since hybrid seed production is a highly technical job and also involves high monetary investment, it is essential to maintain a high level of crop management to maximise production.

In sorghum seed production, the female line is M.S. and solely depends on male lines for pollen supply. Under such situation good stigma receptivity coupled with adequate supply of viable pollens is essential for good seed set. The environmental and edaphic factors also influence seed set and the

total production. In some of the released hybrids like CSH-5, and CSH-9, CSH-8R, there are nicking problems in different seasons. The nicking problem involves non-synchronous flowering of male and female lines, differences in stigma receptivity and pollen viability and the like.

Stigma receptivity studies were performed by Ross (1957) and Mahudeswaran (1959) in two sorghum male sterile lines, under American and Indian conditions, respectively. They concluded that stigmas are receiptive for a period of ten days. Bapat et al. (1967-68) reported that maximum seed set occured between 5th and 10th days after flowering i.e. 100 % on 15th day it was 60 % and on 20th day it was 25 % and stigmas remained receptive for an average of 14-15 days. Karbabaeva (1967) reported that stigma in the sorghum lines A 385 and A 470 remained receptive for several days under irrigated conditions. Seed set was the best when pollinations took place 4 to 7 days, after the start of anthesis. Chopade et al. (1973) reported that the stigma of sorghum lines PMS 1036 A and 2219 A remained receptive for ten and eight days, respectively during the kharif season.

Pollen viability studies were conducted by Psareva (1954) at Voroner. They reported that ripe pollen remained viable, when kept for 12 hours under laboratory conditions and the stigmas were receptive to pollen for three days after the infloresence reached maturity.

Sancher and Smeltzer (1965) reported that pollen kept in the refrigerator at 4°C and 75 % relative humidity remained viable upto 94 hrs after collection, while bagged pollen stored in the shade of plants in the field for more than 20 hrs could still induce seed setting. Storing in the sun and lyophiligation proved ineffectual as storage techniques.

Bapat et al.(1967-68) in their pollen viability study carried out during the rabi season of 1967-68 reported that 100 % seed set was observed when pollination was made immediately after the collection of pollen and this lasted for 2 hours. The seed set comes down to 50 % when pollination was done 4 hours later. Thereafter pollens lost their viability.

In order to meet the over increasing demand of certified seed and also to confirm the varying reports in respect of stigma receptivity and pollen viability, the present study was under taken by including different parental lines of commonly cultivated sorghum hybrids with the following objectives.

1. To know the stigma receptivity of different female lines of sorghum hybrids.
2. To know the period of pollen viability of different male lines of sorghum hybrids.
3. To study the effect of environmental factors like temperature and relative humidity on stigma receptivity and pollen viability in different seasons.

2. REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Sorghum (Sorghum bicolor (L.) Moench) is one of the four major food grain crops of the world and it forms a staple food of millions of people in semi-arid tropics. Sorghum is a food and fodder crop of India. It occupies 16.4 million hectares in the country. Scientific efforts are underway to boost the yield potential of sorghum by developing new hybrids, high yielding varieties and suitable package of practices.

Seed is the most vital but least expensive of the basic inputs of crop production. With the rapid advances in the research programmes of most of the major cereals, to exploit the yield potential, it is necessary to have a sound seed production programme of hybrids and high yielding varieties. Since 1964, nine sorghum hybrids viz. CSH-1 to CSH-9 and nine high yielding varieties viz. CSV-1 to CSV-9R have been released for general cultivation. The flowering behaviour of parental lines of these different hybrids differ considerably and, hence, it is necessary to understand the behaviour of these lines in different seasons to get better seed yields.

Since hybrid seed production is highly technical and involves high monetary investments, it is essential to maintain high level of crop management in order to maximise production. For this, the stigma receptivity and pollen viability studies will help to the seed producing organisations to manupulate

suitably the dates of sowing of the parents of the released hybrids for their proper nicking which will ultimately result in successful seed production.

In sorghum seed production, the female line is male-sterile and solely depends on male lines for pollen supply. Under such situation, good stigma receptivity coupled with adequate supply of viable pollens, results in good seed set. The environmental and edaphic factors also influence seed set and the total production. In some of the released hybrids like CSH-5, CSH-9 and CSH-8R, there are nicking problems in different seasons. The nicking problem involves non-synchronous flowering of male and female lines, differences in stigma receptivity and pollen viability, drying of stigma due to dry weather and the like.

2.1 Stigma receptivity

Stephens (1934) reported that the stigmas of a sorghum flower are receptive to pollen for some time before blooming and for longer time after blooming of the feterita flowers. When pollinated approximately 24 hours before opening, over 50 per cent seed set was observed and those pollinated 48 hours before opening, almost 50 per cent seed set was observed. Since under chillicothe (texas) conditions, the pollen is viable for only a short time, the stigmas were receptive at the time of pollination or shortly thereafter.

If pollination has not taken place, the extruded stigmas of sorghum flowers remain feathery and fresh locking for several days after the glumes have closed, even in mid-summer, and flowers pollinated 8 days after blooming have produced seeds. With the advent of cooler weather in the fall, the stigmas remain fresh for a longer period and successful pollinations were made in early October on Blackhull Kafir stigmas, 16 days after the blooming. The long receptiveness of stigma is of value in hybridizing sorghums, since pollination may be delayed until all the flowers are emasculated for a particular cross has bloomed. When the bulk emasculation method is used and all the flowers in a panicle are to be pollinated, this possible delay in pollination is especially useful, for a week or more frequently is required for the completion of blooming throughout the infloresence. On the other hand, receptive stigmas are always susceptible to natural cross-pollination, and if care is not taken, bags which have been placed on heads to prevent natural crossing may be broken or removed while unpollinated stigmas are still receptive.

Harlan (1944-45) reported that receiptivity of buffalo-grass stigmas remained fairly high for 13 days, after which time it decreased rapidly until no seed was produced on the twenty first (21) day. The duration of receptiveness in corn silks extended over a period of 24 days. Two to twelve days old silks set seed rather uniformly, averaging 60 % seed setting decreased, from 41 % on silks 14 days old to only,

2 % on silks 24 days old. The duration of receptivity of stigmas was 5 days more in corn than in buffalo-grass. The peak receptivity occurred on the 5th day in buffalo-grass and on the 8th day in corn. It was found that with both buffalo-grass and corn, the stigmas continued to grow in length until pollen was applied. Stigmas were observed to grow to the lengths of 1 inch in buffalo-grass and 12 inches in corn.

Charles et al. (1956) reported that stigma receptivity was found to be important. The highest per cent seed set was observed when 1 to 3 days elapsed between emasculation and pollination, and less seed set when pollination followed emasculation on the same day or when more than 3 days separated emasculation and pollination. Stigmas remained receptive longer at lower temperatures than at high temperatures.

Low field temperatures favoured seed set, while high temperatures reduced it. High temperatures between emasculation and pollination, especially when there was an interval of 3 or 4 day, decreased seed set. Most of the pollinations were made in the afternoon because of greater pollen availability, but morning pollinations were satisfactory on some days.

More of the top florets set seed after short intervals between emasculation and pollination, and more of the lower florets set seed after a long interval and stigma receptivity probably was involved. On the day of emasculation, only 3 or

4 of the upermost stigmas were receptive. They remained receptive only 3 or 4 days under conditions at Madison, Wis. Optimum time interval between emasculation and pollination was of 1 to 3 days. Less than a day or greater than 3 days lowered seed set.

Ross (1957) reported that the heads of comparable sizes in 2 excellently derived male-steriles, combine kafir 60(BC_1) and white martin (BC_3) were bagged with aldrin treated bags at the time of head exsertion about 2 or 3 days before the first floret opened. Heads were bagged on different days. The previous experience had shown that a high percentage of seed set could not be expected unless pollinations were made about 1 week after bagging. On such immature heads consequently, the first pollinations were made at 7 days after bagging. Other heads were pollinated at 11 two day intervals thereafter, upto 29 days after bagging.

Five heads of each male-sterile variety were pollinated on each date with bulk pollen from several variation, the bags were replaced after pollination. The chance of contamination from insect-borns pollen was decreased by the use of chemically treated bags. At the harvest, the seed set was estimated to the nearest 5%, and those estimates were confirmed by weighing the threshed grain from each head. The maximum number of florets were receptive 9 days after the heads were bagged, although the apical florets no longer were receptive even 7 days after bagging. In general, the experiment verified previous observations that sorghum floret remains receptive

upto 10 days after opening.

Mahudeswarn (1960) conducted an experiment at Coimbatore, Madras and showed that the stigmas are capable of the remaining receptive upto 10 days after protrusion; while in the USA receptivity declined after the 5th day, in the male sterile line A 385.

Manoliu et al. (1965-67) reported in a three years study of male-sterile lines that the duration of anthesis averaged 5-6 days in A-85 and A-86 and 6-7 days in A-72, stigma receptivity lasted for 7-8 days in the last line and 9-10 days in the first two lines.

Bapat et al. (1967-68) reported that maximum seed set occured from 5th to 10th days of flowering when seed set was 100 %, while it decreased to 60 % on 15th day, and to 25 % on 20th day. Stigma remained receptive for an average of 14 to 15 days.

Konovalov (1969) reported that maximum seed set occured on the sixth day of flowering and stigmas remained receptive for an average of 14-15 days.

Linnik and Yastrebor (1969) reported that maximum seed set resulted from pollination on 6 to 10 days after the beginning of flowering. Receptivity of stigmas for pollen continued until 17th to 24th days. Stigmas of the red grained compact panicles of kafir corn lost receptivity more quickly than those of the white grained lax panicles of grain sorghum.

Kerbabaeva (1970) reported that, in the male sterile lines A-385, A-470, A-476, grown under irrigated conditions stigma receptivity retained for several days after flower opening. The best seed set was observed when pollination took place on 4 to 7 days after the start of anthesis. The lines A-385 and A-470 had good seed set.

Atkins (1971) pollinated bagged heads of each of six male sterile lines at mid-bloom, at full bloom and at five two-day intervals after full-bloom. The results averaged over two years indicated that for all the varieties where pollinations made either two or four days after full bloom were the most effective, averaging 8 % higher seed set than those made at the full-bloom stage. Pollinating heads at six days after full-bloom gave better seed set than that obtained from pollination at the mid-bloom stage. However, varieties differed in the duration of stigma receptivity.

Wanjari and Chopde (1977) studied the stigma receptivity and the seasonal variation in flowering of the parents of sorghum hybrids CSH-3 and CSH-4. Suitable pollination dates for better seed set were found to be 4-8 days and 6-10 days after the initiation of flowering in MS-2219 A and PMS-1036 A, respectively. They further suggested adjustments in the sowing dates of the female and male parents at various times of the year to achieve synchronous flowering.

Anthony and Harlan (1978) reported the highest seed set in barley after 2 days interval between emasculation and pollination. Seed set gradually decreased to none on the sixth day. They attributed most failures in barley hybridization to faulty pollen rather than to a lack of stigma receptivity.

2.2 Pollen Viability

Stephens and Quinby (1934) investigated time of anthesis during the day and the longevity of pollen under several storage conditions. Pollen stored in a refrigerator at room temperature, and in the sun for 24, 30 and 48 hours did not give seed set on emasculated flowers. Pollen stored in the shade and used on emasculated flowers every half hour after collection declined very rapidly from 60 % to 0 % seed set in a five hours' period.

(1) Stephens and Quinby (1934) reported that in barley, after 4 hours of storage, only 3 % of florate set seed, when liberally pollinated with shade stored pollen.

Harrison and Futton (1934) stored cotton pollen successfully under refrigeration, for 2, 3 and 4 days,

1. in buds collected in the afternoon preceeding anthesis
2. in flowers collected in the morning when the anthers were begining to open, and
3. as loose pollen collected in the afternoon when all the anthers were fully open.

Pollen stored in the laboratory at air temperature failed to effect fertilization, whether collected in the bud in the afternoon preceeding anthesis, in the early morning when pollen first becomes available, or in the afternoon when the pollen was fully mature. Pollen stored in a descicator at air temperature over calcium chloride also failed to effect fertilization. With the three methods of storage that proved successful, each additional day of storage resulted in a material reduction in the degree of fecundation effected, whether measured by the percentage of bolls set, or by the number of seeds per boll. Storage of pollen by refrigeration in the flower collected early on the day of anthesis appears to be the most practical of the three methods.

Pope (1939) tested the viability of pollen from the spikes grown in the green house on receptive flowers of growing in green house plant. The pollen stored for 21 days at 36°F was still able to produce seed, while that stored for the same length of time at 40°F failed entirely. Nine days of storage gave a very poor seed set at 36°F and none at 40°F. These pollens, when germinated on receptive flowers and examined ; showed viability of 57 % for storage at 36°F and 29 % for storage at 40°F, with many of the pollen tubes growing weakly and abnormally.

Harlan (1944-45) showed that Buffalo-grass pollen stored in the spike under the temperature of 40°F and a relative humidity of 90 % effected fertilization for 7 days in both years (1944 and 1945). Free pollen stored in a beaker under the same temperature and humidity remained viable for 6 days in 1944 and 8 days in 1945.

The same treatments were applied to corn pollen in 1944 and 1945. Corn pollen stored in the tassel effected fertilization for 9 days in 1944 and 8 days in 1945. Corn pollen stored in a beaker remained viable in part for 8 days. Under this treatment, a very good set of kernels was obtained the first 2 days with the viability decreasing rapidly thereafter.

Franklin et al.(1951) in their study at Aberdeen, Idaho, in very hot days in 1947 reported that oat did not always flower between 2 and 5 P.M. which was believed to be the most common and favourable period of the day for pollination in oats. The oat flowers shade later during the evening on days when maximum temperatures where in the middle or upper nineties. Consequently, on a very warm day, more satisfactory seed set was obtained by delaying crossing operations in oats until late afternoon or evening i.e. after the temperatures had dropped.

On days with a maximum temperatures of 96°F or higher, the average seed set was 3-4% for afternoon pollination made between 2 and 5 p.m. and 24.8 % for evening pollination between 4 and 7.30 p.m., then increase was close to 36 %.

Psareva (1954) observed that, at Voronez, ripe pollen remained viable when kept for 12 hours under laboratory conditions and the stigmas were receptive to pollen for three days after the inflorescence reached maturity.

Charles and Shands (1956) reported that the use of pollen in oat stored at 39°F offered promise in improving pollen quality, but the results were variable. Limited pollinations were made using field and green house grown plants. Panicles were collected at 11 a.m., wrapped in dry paper towels and stored at 39°F. After 2, 3, and 4 hours, storage, conventional crossing procedures resulted in seed set upto 51 %, while pollen stored at 70°F or collected just previous to pollination produced only 20 % seed set. Stored pollen was also used in crossing field grown plants in 1952. The panicles were wrapped in paper towels and placed in the refrigerator overnight at 39°F. Pollination on the following morning yielded from 31 to 65 % seed set. During the following year, similar results were obtained after 2 hours' storage. After 5 days of storage at 52°F, only 12 % seed set was observed. Panicles were again collected from field-grown plants in 1955, and were stored at 39°F overnight. The results were variable and not as promising as in the previous years. Anthers tended to dehisce, thereby limiting usable pollen. If these variations could be overcome, the use of stored pollen might increase seed set, extent the daily crossing period, and assist in matching parents of different flowering times.

Sanchez and Smeltzer (1965) reported that pollen kept in the refrigerator at 4°C and 75 % relative humidity remained viable upto 94 hours after collection, while bagged pollen stored in the shade of plants in the field for more than 20 hours could still induce seed setting. Storing in the sun and lyophilization proved in effectual as storage technique.

Sanchez and Smeltzer (1965) oberved in immediate pollinations no seed set was in the early hours of the morning, eventhough pollens were collected from infloresence in which dehiscance had occured on the previous day. This was also the came for pollen collected form the sun treatment and kept over night. Male sterile heads, on which the bags were placed immediately after pollen collection, were well pollinated, however, pollen from the same bags were used on next day, produced no seed.

Bapat et al.(1967-68) carried out pollen viability study during the rabi season of 1967-68. They indicated that 100 % seed set was observed when pollination was made immediately after the collection of pollen and this lasted for 2 hours. The seed set came down to 50 % when pollination was done 4 hours later and thereafter the pollens lost their viability.

Barrow (1983) studied methods for measuring pollen viability to determine their relative value in evaluating cotton (Gossypium hirsutum L.) pollen. Pollen was treated at constant temperatures of 30, 33, 35, 37, 40 and 43°C for 15 hours prior to anthesis. The treated and untreated pollens

were evaluated using several common techniques. Pollen killed at the highest temperature (43°C) stained readily with a cytoplasmic stain indicating that stains of this type may determine pollen maturity but not viability. Pollen treated at 33 to 40°C responded positively to vital staining and germinated both on artificial media and on the stigma; while the pollen treated at 43°C did not. However, pollen fertility (as measured by pollen tubes penetrating the lower style and ovules) was severely reduced at 33°C. The best available criterion for pollen fertility appears to be tube penetration into the lower style or ovules. Staining and pollen germination methods are not accurate indicators of pollen fertility in cotton.

Bonnie Reger and Sprague (1983) reported that the primary barrier to hybridization of pearl millet (Pennisetum americanum (L.) Leeke) with sorghum (Sorghum bicolor (L.) Moench) is the arrest of pollen tube growth within the genoecium. However, pollen tube growth in this cross is variable. Pearl millet stigmas were receptive to pollen immediately upon the emergence and remained receptive to pollen germination and pollen tube penetration until abscission. Pearl millet pollen tube grows normally in gynoecia having stigmas emerged for more than 4 days (Older gynoecia) resulted in inhibition of pollen tube within the gynoecium. In contrast, sorghum pollen tube growth increased significantly in older Vs younger gynoecia . Sorghum pollen tubes in the every increased from 4 % in younger to 22%

in older gynoecia. Apprently the internal environment of pearl millet genoecia changes with age. These changes appear to alter the pollen tube transmitting tract in the gynoecium making it inhibitory to pearl millet pollen tubes and less inhibitory to sorghum pollen tubes.

2.3 Temperature

Sieglinger (1936) reported that a sorghum plant continues to produce leaves in the meristem until a floral bud is initiated, and the production of an additional leave delays flowering by about 3 days.

Hammer (1940) using the data from soyabeans (Glacine max - (L.) merill), concluded that flower induction is governed by processes in the light, processes in the dark, and processes from an interaction between the two.

Miller et al.(1968) divided the varieties they grew into five classes depending on the day lenghts required to delay floral initiation. The data show that tropical varieties of different maturities have different critical dark periods and that tropical varieties need longer nights to allow floral initiation than temperate varieties. Temperate varieties, many of which will flower in continuous light, have no critical dark periods but differ in the length of night that will delay floral initiation. All this information leads to the conclusion that the photoperiodic effect is apparent only if the nights are too short to allow the synthesis of auxin, to allow early floral initiation.

Caddel and Weibel (1971) found that the effect of night temperature on photoperiodic response depends upon the day temperature as well as on the variety and that day temperature was more important in determining the length of panicle development than the time needed to reach floral initiation.

Quinby J.R. (1972) observed that the late maturing variety PI 276769 did not flower in Puetro Rico, until November when planted in any month from January to August. Apparently, floral initiation took place in October when the nights were about 12.2 hours long. PI 291227 a rabi (winter growing) variety from India, flowered in October in Puerto Rico when planted in any month from March to August. Apparentlly floral initiation took place when the nights were about 11.8 hours long. TEXAS BLACKHULL KAFIR is a temperate variety that was grown extensively in the southern great plains fifty years ago. This variety was not delayed greatly in flowering in any planting even when the nights were shorter than 11 hours.

3. MATERIAL AND METHODS

3. MATERIAL AND METHODS

The present investigation was undertaken to elicit information for stigma receptivity and pollen viability in different parental lines of sorghum hybrids to support the planning for successful seed production programme. This study involved the restorer lines like IS-84, CS-3541, 168, Swarna, PD 3-1-11 and female (male-sterile) lines like CK-60A, 2077A, 2219A, 296A and 36A. The research work was carried out at Mahatma Phule Agricultural University, Central Campus, Rahuri, during the period 1983-84 (Summer 1983, kharif 1983 and rabi 1983-84).

The materials used and statistical procedures followed during the course of present investigation are described in the following pages.

3.1 Material

Five females (male sterile) viz., CK-60A, 2077A, 2219A, 296A and 36A and five pollinator parents (male) viz., IS-84, CS-3541, 168, Swarna and PD 3-1-11 were selected for the present investigation. The seed of these females and male parents was obtained from the All India Co-ordinated Sorghum Improvement Project, Mahatma Phule Agricultural University, Rahuri. The details about these parents are given in Table-1.

Table 1. Description of parents

Table 1 (a) Male-sterile lines

Parent	Pedigree	Sailent features
1. CK-60A	Combine kafir type Texas (milo cyto)	Non tan plant type, dark green leaf, sheath encloses stem, thick and juicy stalk, elongated semicompact earhead, white chalky grain, glume dark purple, covering more than half. White shrivelled anthers.
2. 2077A	IS-2077 yellow endosperm	Tan plant type semierect broad straight leaf, sheath encloses stem, thick and juicy stalk, semiloose, large and oblong earhead, pearly grain, straw coloured short glume, shrivelled yellowish anthers.
3. 2219A	IS-2219 yellow endosperm type (6323) Nebraska, USA (Welastern)	Tan plant type, light green semi-erect leaf, sheath encloses stem, thick and juicy stalk, semi-compact elongated earhead, whi-tish pearly grains, pinkish coloured glumes, shrivelled white anthers.
4. 296A	IS-3922 x Karad local	Tan type dark green semierect broad leaf, sheath encloses stem, thick and juicy stalk, earhead semicompact, oval, tapering towards end, pearly shining grain, straw coloured glume, shrivelled white anthers.
5. 36 A	Derivative of PJ16K x CK-60B	Non tan plant type dark green leaf, thick and juicy stalk, compact oblong earhead, pearly white grain, black purple glumes, Shrivelled white anthers.
b) Male parental lines		
1. IS-84	Selection from yellow endo-sperm feterita of hybrid origin USA (SA-7529)	Green yellowish broad leaf drooping down and sheath enclo-ses stem, thick and juicy stalk, earhead elongated, semiloose tapering towards apex, light yellow endosperm grain, straw coloured glume, grain almost exposed non tan plant type.

contd.....22/-

Table 1 (contd....)

Parent	Pedigree	Sailent features
2. CS-3541	Darivative of a cross IS-3675 x IS-3541.	Tan plant type, small pear shaped pearly and cream coloured grain, narrow leaves, leaf margins wavy, light redish purple glumes, grain mold resistant pearly white grains.
3. 168	IS-3687 x Aispuri 70-75	Tan plant type dark green broad leaf drooping downward sheath encloses stem, thick and juicy stalk compact earhead, pearly coloured grain medium round and 1/3 covered glume.
4. Swarna	Selection from IS-3924(caffro-rum) SA-980A big seed YE. California USA.	Green semierect leaves in the middle and somewhat errect towards the top, sheath encloses the stem, thick and juicy stalk, earhead semi-compact oblong tapering towards end. Bold yellowish white seed, purple ½ covered glume. Non tan plant type.
5. PD-3--1-11	Selection from the crosses (IS-84 x BP-53)	Green broad leaves, thick and juicy stalk semiloose, ablong; conical earhead, pearly shining grain colour, straw coloured glume 1/4 covered. Non tan plant type.

3.2 Experimental layout

The stigma receptivity and pollen viability studies were conducted by following factorial randomised block design and by including five male-sterile lines and five male(pollinator) lines at Post-Graduate area, Mahatma Phule Agricultural University, Rahuri. Carbofuran seed treatment was given before sowing the seed. The experiment was replicated two times. Each replication consisted of 5 male steriles and 5 restores. The

inter row spacing of 45 cm and inter plant spacing of 15 cm was kept.

The seeds per hill were hand dibbled and thinned to single plant per hill after eight days of germination to maintain a uniform plant population. The gap filling was also carried out ten days after the sowing. For good crop stand the crop was raised under the recommended dose of fertilizer, and other management practices in summer,1983, kharif,1983 and rabi,1983.

3.3 Methods

The seeds of the parents were sown during summer 1983, kharif 1983, and rabi 1983 at the Post-Graduate area of Department of Botany.

Fourty four (44) earheads from each male-sterile line were selfed on a day before the start of blooming. Four plants from each group were hand pollinated after full blooming and the same procedure was followed by keeping the one day gap between each pollination as a starvation period and continued upto 15 days for stigma receptivity studies and for pollen viability studies four plants from each group were hand pollinated immediately after the collection of pollens from restores in a brown paper bag and the same procedure was followed by keeping 2 hours' interval in each pollination and continued upto 8 hours. Sufficient quantity of pollens from restores were collected in brown paper bags before the actual starting

of the crossing. Hand pollination was followed for crossing. At the maturity stage, each earhead was harvested separately.

3.4. Observations to be recorded

3.4.1. Stigma Receptivity studies

1. Date of start of flowering
2. Date of full blooming
3. Date of 1st pollination i.e. on 1st day of full blooming.
4. Date of 2nd pollination i.e. on 3rd day of full blooming.
5. Date of 3rd pollination i.e. on 5th day of full blooming.
6. Date of 4th pollination i.e. 7th day of full blooming
7. Date of 5th pollination i.e. 9th day of full blooming
8. Date of 6th pollination i.e. 11th day of full blooming (by keeping one day starvation period between each pollination).

3.4.2. Pollen viability studies

1. Pollination immediately after anthesis
2. Pollination 2 hours after anthesis
3. Pollination 4 hours after anthesis
4. Pollination 6 hours after anthesis
5. Pollination 8 hours after anthesis

3.5 Temperature

Maximum and minimum temperature was recorded during summer 1983, kharif 1983 and rabi 1983-84.

3.6 Biometrical analysis

The data was collected for each of the characters from the four plants which were hand pollinated. The per cent seed setting per panicle was calculated for respective starvation period in stigma receptivity and pollen viability studies. The angular transormation was done by following the standard table given by Fisher and Yates (1961). The population means for each replication were calculated from the individual plant data and these means were used for the analysis of variance. The ANOVA has been given below (Panse and Sukhatme 1961).

3.6.1 ANOVA for stigma receptivity studies

Source	d.f.	Mean sum of square			'f' ratio
		Summer 1983	Kharif 1983	Rabi 1983-84	
Replication	r-1				
Treatments					
Male sterile line	(MS-1)				
Starvation period	(SP-1)				
Male sterile line x Starvation period	(MS-1) x (SP-1)				
Error	(r-1) x (MS x SP-1)				
Total	(n-1)				

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3.6.2 ANOVA table for pollen viability studies

Source	d.f.	Mean sum of squares			'f' ratio
		Summer 1983	Kharif 1983	Rabi 1983	
Replication	r-1				
Treatments					
Restorer lines	(RS-1)				
Pollination period	(PP-1)				
Restorer lines x Pollination period	(RS-1) (PP-1)				
Error	(r-1) (RS x PP-1)				
Total	(n-1)				

Where,

r = Number of replications i.e. two

t = Number of treatments

RS = Number of restores lines

PP = Number of pollination periods

MS = Number of male sterile line

SP = Number of starvation period
i.e. 6 starvation periods for stigma receptivity and 5 for pollen viability (i.e. 5 pollination period)

3.7 Standard error

The formula for standard error is given below.

3.7.1 Stigma receptivity

a) S.E. for starvation period

$$S.E. = \sqrt{\frac{E.M.S.}{r \times m}}$$

m = male sterile lines

r = Replications

EMS = Error mean sum of squares

b) S.E. for male sterile lines

$$S.E. = \sqrt{\frac{E.M.S.}{r \times sp}}$$

EMS = Error mean sum of square

r = Number of replications

sp = Number of starvation periods

c) S.E. for interaction (male sterile x starvation period)

$$S.E. = \sqrt{\frac{E.M.S.}{r}}$$

EMS = Error mean sum of squares

r = Number of replication

3.7.2 Pollen Viability

a) SE for pollination period

$$\sqrt{\frac{E.M.S}{r \times RL}}$$

r = Number of replication

RL = Number of restorer lines

b) S.E. for restorer lines

$$S.E.= \sqrt{\frac{E.M.S.}{r \times sp}}$$

c) S.E. for interaction (male sterile x pollination period)

$$S.E.= \sqrt{\frac{E.M.S.}{r}}$$

Where,

EMS = Error mean sum of square

sp = Number of pollination period

m = Number of male sterile lines

r = Number of replications

3.7.3 Critical difference (C.D.)

Critical difference was calculated by using t values at respective error degrees of freedom at 5 % and 1 % level of significance.

3.8 Test significance

In the variance ratio table ('f' cal.) calculated values for male sterile lines, starvation period, pollination period and interaction (male sterile x starvation period) if greater than the table values of F at 5% and 1% level of significance, then the difference was considered to be significant if not and it was treated as non-significant.

4. EXPERIMENTAL RESULTS

4. EXPERIMENTAL RESULTS

The present investigation of stigma receptivity and pollen viability in different parental lines of released sorghum hybrids was undertaken with a view to know the period of receptivity and viability of stigma and pollen respectively. The experimental material consisted of five male sterile lines viz. CK-60A, 2077A, 2219A, 296A and 36A and five restorer lines viz., CS-3541, IS-84, 168, swarna and P.D.3-1-11. The receptivity of stigma and pollen viability was studied as indicated below.

4.1 Stigma receptivity

Per cent seed setting was worked out by pollinating panicles at different periods after the emergence of stigma.

1. Immediate pollination
2. 3rd day pollination
3. 5th day pollination
4. 7th day pollination
5. 9th day pollination
6. 11th day pollination

4.2 Pollen viability

Pollen viability study was undertaken by pollinating bagged ears with collected pollens at different periods.

7. Pollination immediately after anthesis
8. Pollination after 2 hrs from anthesis
9. Pollination after 4 hrs from anthesis
10. Pollination after 6 hrs from anthesis
11. Pollination after 8 hrs from anthesis

Table 2. Analysis of variance for different seasons (stigma receptivity)

Source	Degrees of freedom	Mean sum of squares		
		Kharif	Rabi	Summer
Replication	1	0.34	0.04	0.07
Treatments Male sterile lines	4	74.55*	148.07*	3163.31*
Starvation period	5	2642.77*	2588.68*	3011.89*
M.S. x starvation (Interaction)	20	20.12*	22.83*	104.76*
Error	29	0.11	0.10	0.11

* Significant at 5 % level.

4.1 Stigma receptivity

4.1.1 Mean performance of the parents of the different hybrids

From ANOVA(Table-2) it was revealed that the male-sterile lines, starvation periods, and the interaction between male-sterile line and starvation period effects were significant, for all the three seasons.

The data of seed setting in different seasons are presented in Tables 3, 4 and 5 . Maximum seed setting (52.42 to 59.30 %) was observed in the kharif season followed by rabi (48.12 to 57.23 %) and the summer season (14.44 to 54.24 %). Amongst the 'A' lines 2219 A showed the highest seed setting in all the seasons, while 36 A showed the least seed setting in the summer and rabi seasons.

4.1.2 Per cent seed setting at different starvation periods

4.1.2.1 Kharif

The results indicated that (Table 3) in all the male-sterile lines maximum seed setting was observed in the case of pollination effected immediately after the emergence of stigma. Seed setting decreased significantly in each successive starvation period. Amongst the 'A' lines, the highest seed setting was observed in the pollination that was effected upto the 5th day of the emergence of stigma in 296 A(79.78 to 65.95 %) followed by 2219A(77.91 to 64.23). The lowest seed setting was observed in 36 A(70.22 to 61.13 %) for same starvation period. At the 11 days starvation period, significantly

highest (33.74 %) and lowest (25.62 %) seed setting were observed in the lines 2219A and CK 60A, respectively. Less than 50 per cent seed setting was observed when the earheads were pollinated after 9 day of starvation period (13th day from stigma emergence). On the mean performance basis over different starvation period 2219 A showed significantly highest seed setting as compared to the rest of the lines. Similarly, all the lines showed good (49.95 to 57.23 per cent) seed setting in respect of pollination effected upto the 7th day of the starvation period. Amongst the different male-sterile lines, MS 2219 A was superior to the rest of the MS lines, as in this line even after 9 days of starvation 54.24 per cent seed set was observed (i.e. 13 days after emergence of stigma). More than 50 % seed set was observed in all the lines, when pollinated after the 7th day of starvation (i.e. 11 days after emergence of stigma). The seed setting was 57.23 per cent, 57.10 per cent, 54.27 per cent and 52.09 per cent in 2219 A, 2077 A, 36 A and 296 A, respectively. In the case of CK-60A it was 49.95 per cent. The seed setting started declining when pollinations were effected after 11 days of starvation (i.e. 15 days after emergence). The seed setting was 33.74 per cent, 31.24 per cent, 30.49 per cent, 26.78 per cent and 25.62 per cent in 2219A, 36A, 2077A, 296A and CK-60A, respectively. Thus, it could be seen that the highest per cent seed setting was observed in the case of immediate pollination (70.22 to 79.78 per cent), while reasonably good setting was observed,

Table 3. Mean percentage of seed setting in male sterile lines after pollination at different days from emergence of stigma - Kharif, 1983.

Sr. No.	Male sterile lines	Starvation periods						Mean
		Imme-diate	3rd day	5th day	7th day	9th day	11th day	
1.	CK 60 A	72.64 (91.10)	65.31 (82.60)	62.03 (78.01)	49.95 (58.66)	39.02 (39.66)	25.62 (18.72)	52.42
2.	2077 A	72.19 (90.73)	65.84 (83.25)	62.34 (78.40)	57.16 (70.60)	45.37 (50.64)	30.49 (25.87)	55.56
3.	2219 A	77.91 (95.60)	68.49 (86.67)	64.23 (81.10)	57.23 (70.73)	54.24 (65.82)	33.74 (30.86)	59.30
4.	296 A	79.78 (96.77)	72.05 (90.50)	65.95 (83.40)	52.09 (62.24)	41.96 (44.62)	26.78 (20.32)	56.43
5.	36 A	70.22 (88.64)	63.65 (80.33)	61.13 (76.70)	54.57 (66.40)	48.73 (56.56)	31.24 (26.91)	54.92
	Mean	74.54	67.06	63.13	54.20	45.86	29.57	

(Figures in parentheses are original figures)

	S.E.±	C.D.at 5%
M. S. line	0.09	0.28
Starvation	0.10	0.30
M.S. x Starvation period(Interaction)	0.23	0.69

when pollination was effected on 5th day (61.13 to 65.95 per cent) and the lowest seed setting was observed in the pollination which were effected on 5th day (61.13 to 65.95 per cent) and the lowest seed setting was observed in the pollination which were effected on 11th day (25.62 to 33.74 per cent).

4.1.2.2 Rabi

The results indicated that (Table 4) in all the male-sterile lines maximum seed setting was observed in the case of pollinations effected immediately after the emergence of stigma. Seed setting decreased from each successive starvation period. Amongst the 'A' lines the highest seed setting was observed in the pollinations that were effected upto the 5th day of starvation period (9 days from emergence of stigma) in 2219 A (75.34 to 62.24 per cent) followed by 296 A (74.06 to 63.80 per cent). While the lowest seed setting was observed in 36 A (62.51 to 51.18 per cent).

More than 50 per cent seed setting was observed in 2077 A(56.04 per cent), 2219 A(55.70 per cent) and 296 A (50.41 per cent) when pollinated after 7 days of starvation (i.e. 11 days after emergence of stigma). In the case of 36 A and CK 60 A, it was 49.92 per cent and 45.91 per cent, respectively. However, amongst all the different male-sterile lines the M.S. line 2219A was superior to the rest of the M.S. lines, since in this line even after the 9th day of starvation 52.39 per cent seed set was observed (i.e. 13 days after emergence of stigma). At the 11 days starvation

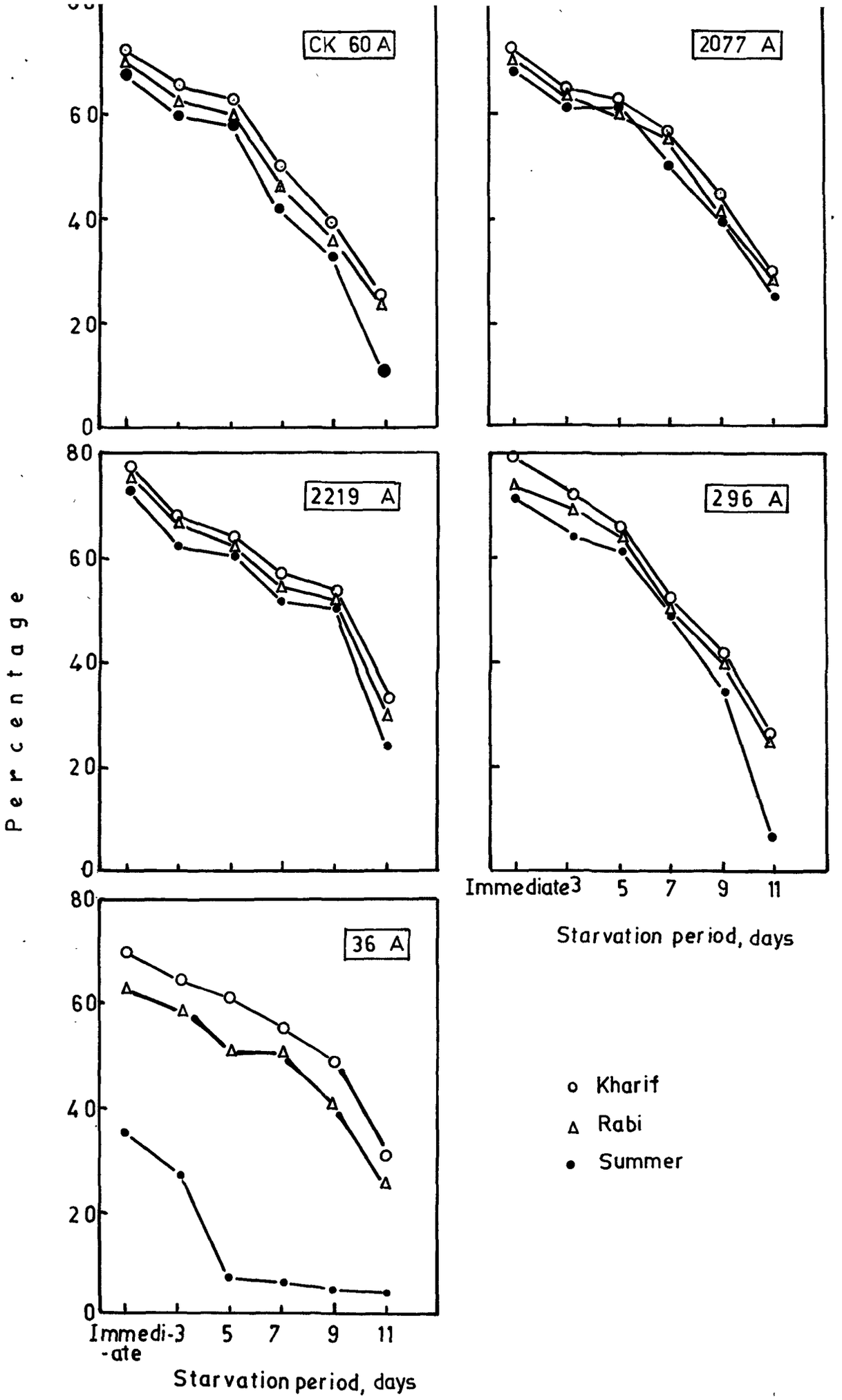

Fig. 1. Percent seed setting in different male sterile lines after pollination at different days from emergence of stigma.

Table 4. Mean percentage of seed setting in male sterile lines after polination at different days from emergence of stigma - Rabi, 1983-84

Sr. No.	Male sterile	Starvation periods						Mean
		Imme-diate	3rd day	5th day	7th day	9th day	11th day	
1.	CK 60 A	70.86 (89.28)	63.94 (80.72)	60.43 (75.67)	45.91 (51.62)	36.66 (35.72)	23.69 (16.18)	50.24
2.	2077 A	69.91 (88.24)	64.67 (81.73)	60.46 (75.77)	56.04 (68.81)	42.85 (46.28)	28.21 (22.37)	53.69
3.	2219 A	75.34 (93.62)	67.33 (85.25)	62.24 (78.32)	55.70 (68.32)	52.39 (62.73)	30.43 (30.38)	57.23
4.	296 A	74.06 (92.40)	68.99 (87.10)	63.80 (80.52)	50.41 (59.42)	39.64 (40.74)	24.23 (16.88)	53.52
5.	36 A	62.51 (78.74)	58.12 (72.14)	51.18 (60.72)	49.92 (58.62)	40.45 (42.10)	26.56 (20.02)	48.12
	Mean	70.53	64.61	59.62	51.59	42.39	26.62	

(Figures in parenthesis are original figures)

	S.E.±	C.D.at 5%
M.S. line	0.09	0.27
Starvation	0.10	0.29
M.S. x Starvation period(Interaction)	0.22	0.66

period significantly highest (30.43 per cent) and lowest (23.69 per cent) seed setting was observed in the lines 2219A and CK-60A, respectively. The seed setting started was least when pollinations were effected after 11 days starvation (i.e. 15 days after emergence stigma) period. The seed setting was 30.43 per cent, 28.21 per cent, 26.50 per cent, 24.23 per cent 23.69 per cent in 2219A, 36 A, 296 A and CK-60A, respectively.

On the mean performance basis over different starvation periods, 2219A showed significantly highest seed setting as compared to the rest of the lines. Similarly, all the lines showed good (51.59 to 70.53 per cent) seed setting in respect of pollination effected upto the 7th day of starvation period (i.e. 11 days after stigma emergence).

Thus, it could be seen that the highest per cent seed setting was observed in the case of immediate pollination (62.51 to 75.34 per cent), while reasonably good seed setting was observed when earheads were pollinated on 5th day of starvation period (51.18 to 63.80 per cent) and the lowest seed setting was observed in pollinations which were effected on the 11th day (23.69 to 30.43 per cent) i.e. 15 days after stigma emergence.

4.1.2.3 Summer

In this season, in all the male sterile lines maximum seed setting was observed in the case of pollination effected immediately after the emergence of stigma (Table 5). Seed

setting decreased from each successive starvation period. Amongst the 'A' lines, the highest seed setting was observed in the pollination that was effected upto the 5th day of the emergence of stigma in 2077A(68.53 to 61.61 per cent) followed by 296 A and 2219A (71.90 to 60.73 and 73.57 to 60.63 %) respectively . The lowest seed setting was observed in 36 A (35.58 to 6.91 %). At the 11 day of the starvation period, significantly highest (25.73 %) and lowest (5.59 %) seed settingswere observed in the lines 2077A and 36A, respectively. Less than 50 per cent seed setting was observed when the ear-heads were pollinated after the 11th day from emergence of stigma.

On the mean performance basis over different starvation period, 2219A showed significantly highest seed setting as compared to the rest of the lines. Similarly, except 36A, all the lines showed good (58.66 to 61.61 %) seed setting in respect of pollination effected upto 5th day of starvation period. Amongst the different male sterile lines, the variety M.S. line 2219A was superior to the rest of the M.S. lines, since in this line even after the 9th day of starvation 51.00 per cent seed set was observed (i.e. 13 days after emergence of stigma). More than 50 per cent seed set was observed in 2077A (61.61 %), 296 A (60.73 %), 2219 A (60.63 %), and CK-60A (58.66 %) when pollinated after 5th day starvation period (i.e. 9 days after emergence of stigma), whereas in the case of 36 A, it was 6.91 per cent. The seed setting started declining when pollinations were effected after 11 days of starvation (i.e. 15 days after emergence of stigma).

Table 5. Mean percentage of setting in male sterile lines after pollination at different days from emergence of stigma - Summer, 1983

Sr. No.	Male sterile lines	Starvation periods						Mean
		Imme-diate	3rd day	5th day	7th day	9th day	11th day	
1.	CK 60 A	68.95 (87.14)	60.03 (75.10)	58.66 (72.86)	42.83 (46.18)	32.89 (29.53)	10.93 (3.63)	45.71
2.	2077 A	68.53 (86.59)	61.89 (77.82)	61.61 (77.44)	51.70 (61.60)	41.58 (42.33)	25.73 (18.82)	51.84
3.	2219 A	73.57 (92.01)	62.90 (79.23)	60.63 (75.92)	52.56 (63.11)	51.00 (60.40)	24.80 (17.60)	54.24
4.	296 A	71.90 (90.40)	63.87 (80.60)	60.73 (76.10)	49.63 (58.00)	35.55 (33.80)	7.6 (1.82)	48.21
5.	36 A	35.58 (33.84)	26.70 (20.21)	6.91 (1.45)	6.01 (1.10)	5.88 (1.01)	5.59 (0.92)	14.44
	Mean	63.70	55.07	49.70	40.54	33.38	14.93	

(Figures in parentheses are original figures)

	S.E.±	C.D, at 5%
M.S. line	0.09	0.28
Starvation	0.10	0.31
M.S. x Starvation period (Interaction)	0.24	0.69

The seed setting was 25.73 per cent, 24.80 per cent, 10.93 per cent, 7.60 per cent and 5.59 per cent in 2077 A, 2219A, CK-60A, 296 A and 36 A, respectively. Thus, it could be seen that the highest per cent seed setting was observed in the case of immediate pollination (35.58 to 73.57 %) while reasonably good seed setting was observed when pollinated on the 5th day (58.66 to 61.61 %) except in 36 A (6.91 %) and the lowest seed setting was observed in the pollinations which were effected on the 11th day (5.59 to 25.73 %).

In general, seed setting was the highest in the kharif season followed by the rabi and summer seasons for all the starvation periods studied. In all the three seasons, more than 50 per cent (51.18 to 65.95 %) seed setting was observed in most of the 'A' lines tried. In the case of pollinations effected after 5 days of starvation period (i.e. 9 days after stigma emergence), 296A showed the highest seed setting, in the kharif (65.95 %) and rabi (63.80 %) season, while in summer seed setting was the highest in 2077 A (61.61 %). In 36 A though the seed setting was the lowest in all the seasons, better seed setting was observed in kharif (61.18 %) and in rabi (51.18 %). While it was negligible in summer (6.91 %). In the case of pollinations effected after 5 days of starvation period (i.e. 9 days after stigma emergence) indicating its sensetivity to temperatures and relative humidity.

In all the seasons, rapid reduction in seed setting was noticed in CK-60A followed by 296 A at the 7th day of starvation period (i.e. 11 days after stigma emergence). At the

11th day of the starvation (i.e. 15 days after stigma emergence) period, 2219 A showed the highest per cent seed setting in kharif (33.74 %) and rabi (30.43 %), while in summer it was the highest in 2077 A (25.73 %) followed by 2219 A (24.80 %).

In general, the results revealed that in all the seasons maximum seed setting(over different starvation periods) 59.30, 57.23 and 54.24 % was observed in 2219 A respectively in kharif , rabi and summer seasons. 36 A showed the least seed setting in rabi (48.12 per cent) and summer (14.44 per cent).

4.2 Pollen Viability

4.2.1 Mean performance of parents of the different hybrids

Significant differences were observed amongst the restorer lines, pollination periods, and interaction between restorer lines and pollination period effects (ANOVA Table 6).

The data of seed setting in different seasons have been presented in Tables 7, 8 and 9. Maximum seed setting (48.20 to 51.94 %) was observed in pollinations effected during the kharif season, followed by rabi (44.10 to 47.64 per cent) and summer (32.05 to 37.48 per cent). Amongst the different restorer lines, maximum seed set was obtained when the male-sterile line 36 A was pollinated with pollens from PD 3-1-11,

immediately after the collection in all the seasons. While the least seed set was observed in 2219 A in the rabi and summer seasons when pollinated with pollens from 168.

4.2.2 Per cent seed setting at different pollination periods

4.2.2.1 Kharif

The results indicated that (Table 7) maximum seed setting was observed when pollinations were effected immediately after the collection of pollen grains. Seed setting decreased significantly with successive delayed pollinations. Amongst the different restorer lines, the highest seed setting was observed when the pollinations were effected restorer lines, the highest seed setting was observed when the pollinations were effected upto 4 hrs. after the collection of pollen grains in PD 3-1-11 (77.47 to 49.88 %) and was followed by Swarna (75.68 to 47.52 %) for the same period and relatively less seed set was observed in CS-3541 (71.34 to 50.59 %). The seed set came down to 50 % when pollinations were effected 4 hrs after the collection of pollens. It was 52.15, 50.59, 49.88, 49.63 and 47.52 per cent for 168, CS-3541, PD 3-1-11, IS-84 and Swarna, respectively. Thereafter pollen grains lost their viability considerably.

Only 27.78 to 37.54 per cent seed set was observed when pollinations from different restorer lines were done 6 hrs after the collection of pollens while it was reduced to 22.71 to 25.28 per cent when pollinations were effected 8 hrs after collection of pollens.

Table 6. Analysis of variance for different seasons (Pollen viability)

Source	d.f.	Mean sum of squares		
		Kharif	Rabi	Summer
Replication	1	2.62	6.06	2.79
Treatments M.S. lines	4	27.76*	23.39*	40.21*
Pollination period	4	4873.35*	4623.40*	8683.16
M.S. line x pollination period(Interaction)	16	9.72*	13.46*	8.07
Error	24	4.37	5.18	2.50

* Significant at 5 % level.

Table 7. Mean percentage of seed setting in male sterile lines when pollinated at different hours after collections of pollens from restorer lines (Pollen viability) Kharif, 1983.

Sr. No.	Restorer lines	Pollination period in hrs					Mean
		Imme-diate	2 hours	4 hours	6 hours	8 hours	
1.	IS-84	71.41 (89.87)	69.76 (88.12)	49.63 (58.03)	28.45 (22.72)	24.90 (17.78)	48.83
2.	CS-3541	71.34 (89.80)	68.62 (86.72)	50.59 (59.72)	27.78 (21.72)	22.71 (14.90)	48.20
3.	168	73.70 (92.18)	70.41 (88.72)	52.15 (62.45)	37.54 (37.23)	24.10 (16.72)	51.58
4.	Swarna	75.68 (93.87)	70.09 (88.45)	47.52 (54.45)	30.83 (26.32)	23.34 (15.72)	49.49
5.	PB-3-1-11	77.47 (95.32)	70.09 (88.45)	49.88 (58.52)	36.99 (36.24)	25.28 (18.24)	51.94
	Mean	73.92	69.79	49.95	32.31	24.06	

(Figures in parenthesis are original figures)

	S.E.±	C.D. at 5%
Restorer lines	0.61	1.92
Pollination period	0.61	1.92
Restorer line x pollination period (Interaction)	1.47	4.30

In this season, amongst the different restorer lines, the highest per cent seed set was observed when the pollinations were effected by utilizing pollens of PD 3-1-11 (51.94 %), whereas it was the least in CS-3541 (48.20 %). Next to PD 3-1-11 the restorer 168 also showed good seed setting (51.58 %) and both were on par with each other. However, amongst the different restorer lines, PD 3-11-1 was superior to the rest of the lines. Even when pollination were effected 8 hrs after the collection of pollen, 25.28 per cent seed set was observed in this line. The seed setting for the same period was 24.90, 24.10, 23.34 and 22.71 per cent in IS-84, 168, Swarna and CS-3541, respectively.

On the mean performance basis over different pollination periods, PD 3-1-11 showed significantly highest seed setting as compared to the rest of the restorer lines. Similarly, all the lines showed good seed setting (49.95 to 73.92 %) in respect of pollinations effected upto 4 hrs.

Thus, it could be seen that the highest per cent seed setting (71.34 to 77.47 per cent) was observed in the case of immediate pollination (i.e. pollinations effected immediately after anthesis), while reasonably good seed setting was observed when earheads were pollinated 4 hrs after anthesis (47.52 to 52.15 %). Some seed setting was also observed when pollinations were effected 8 hrs after the collection of pollens (22.71 to 25.28 %).

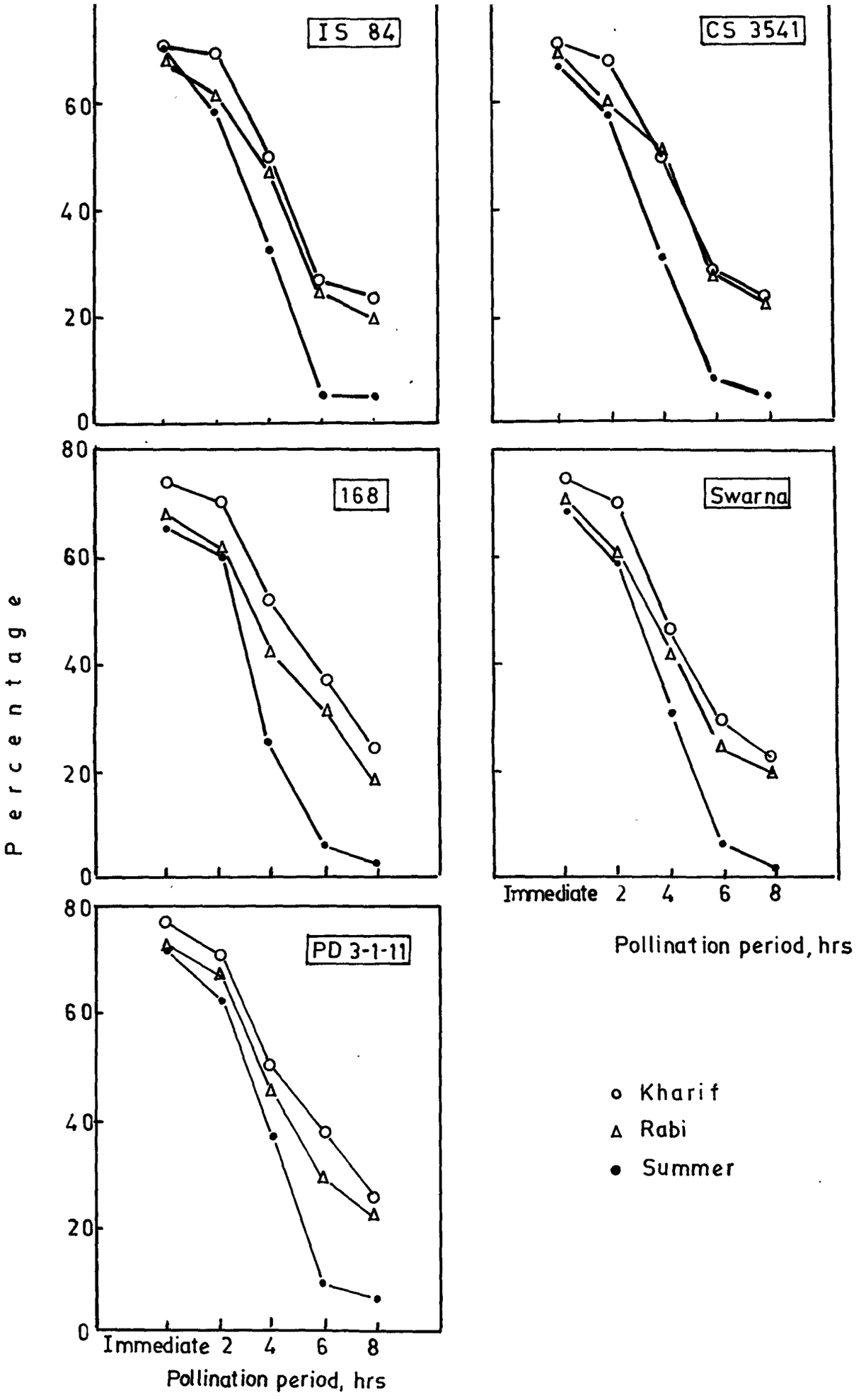

Fig. 2. Percent seed setting in male sterile lines polinated at different hours after collection of pollens from various restorer lines.

In general, in the kharif season, longer pollen viability was noticed in PD 3-1-11 as 25.28 per cent, seed set was observed when pollinations were affected 8 hrs after the collection of pollen grains. The next best for this period was CS-3541 with 22.71 per cent seed set.

4.2.2.2 Rabi

The results indicated that maximum seed setting (Table 8) was observed when pollinations were effected immediately after the collection of pollen grains. Seed setting decreased with the successive delayed pollinations. Amongst the different restorer lines, the highest seed setting was observed when the pollinations were effected upto 4 hrs after the collection of pollen grains in PD 3-1-11 (73.94 to 45.34 %) and was followed by Swarna (71.01 to 42.38 %) while relatively less seed set was observed in 168 (68.70 to 42.49 %). The seed set came down to 50 % when pollinations were done 4 hrs after the collections of pollens. It was 51.83, 47.76, 45.34, 42.49 and 42.38 per cent for CS-3541, IS-84, PD 3-1-11, 168 and Swarna, respectively. Thereafter pollen grains lost their viability considerably.

Seed setting varied from 25.32 to 30.77 per cent when pollinations from different restorer lines were done 6 hrs after the collection of pollens. It was only 17.76 to 22.42 per cent when pollinations were effected 8 hrs after the collection of pollens.

Table 8. Mean percentage seed setting in male sterile lines when pollinated at different hours after collections of pollens from restorer lines (Pollen viability) Rabi, 1983-84

Sr. No.	Restorer lines	Pollination period in hrs					Mean
		Immediate	2 hours	4 hours	6 hours	8 hours	
1.	IS 84	68.72 (88.82)	62.02 (78.01)	47.76 (54.82)	25.32 (18.32)	20.14 (11.92)	44.79
2.	CS-3541	69.79 (88.10)	60.22 (75.32)	51.83 (61.84)	27.73 (21.74)	21.95 (14.02)	46.30
3.	168	68.70 (86.82)	60.81 (76.22)	42.49 (45.62)	30.77 (26.22)	17.76 (9.32)	44.10
4.	Swarna	71.01 (89.45)	61.18 (76.82)	42.38 (45.42)	25.73 (18.88)	20.62 (12.40)	44.18
5.	PD 3-1-11	73.94 (92.32)	67.94 (85.92)	45.34 (50.62)	28.58 (22.92)	22.42 (14.60)	47.64
	Mean	70.43	62.43	45.96	27.62	20.57	

(Figures in parenthesis are original figures)

	S.E.±	C.D.at 5%
Restorer lines	0.71	2.09
Pollination period	0.71	2.09
Restorer line x Pollination period (Interaction)	1.60	4.68

In the rabi season, amongst the different restorer lines, the highest per cent seed set was observed when the pollinations were effected by utilizing pollens of PD 3-1-11(47.64 %), whereas it was the least in 168 (44.10 %). Next to PD 3-1-11, restorer CS-3541 also showed good seed setting (46.30%) and both were on par with each other. However, amongst the different restorer lines, PD 3-1-11 was superior to the rest of the restorer lines. Even when pollinations were effected 8 hrs after the collections of pollen, 22.42 per cent seed set was observed in this line. The seed setting for the same period was 21.95, 20.62, 20.14 and 17.76 in CS-3541, Swarna, IS-84 and 168, respectively.

On the mean performance basis over different pollination periods, PD 3-1-11 showed significantly highest seed setting as compared to the rest of the restorer lines. Similarly, all the lines showed good seed setting (45.96 to 73.94 %) in respect of pollinations effected upto 4 hrs.

Thus, it could be seen that the highest per cent seed setting (68.70 to 73.94 per cent) was observed in the case of immediate pollination i.e. the pollination effected immediately after anthesis, while reasonably good seed setting was observed when earheads were pollinated upto 4 hrs after anthesis (42.38 to 51.38 per cent) and the least seed setting was observed when pollinations were effected 8 hrs after the collection of pollens (17.76 to 22.42 %).

In general, in the rabi season, longer pollen viability was noticed in PD 3-1-11 since 22.42 per cent seed set was observed when pollinations were effected 8 hrs after the collection of pollen grains followed CS-3541 with 21.95 per cent seed set.

4.2.2.3 Summer

Maximum seed setting was observed in this season when pollinations were effected immediately after the collection of pollen grains (Table 9). Seed setting decreased with successive delayed pollinations. Amongst the different restorer lines, the highest seed setting was observed when the pollinations were effected upto 2 hrs after the collection of pollen grains in PD 3-1-11 (72.07 to 61.75 %) followed by IS-84 (71.26 to 59.08 %), while relatively less seed set was observed in 168 (65.89 to 60.40 %). The seed set was less than 50 % when pollinations were effected 4 hrs after the collection of pollens. It was 37.28, 33.05, 31.81, 31.25, and 25.10 per cent for PD 3-1-11, IS-84, Swarna, CS-3541 and 168, respectively. Thereafter, pollen grains lost their viability very rapidly.

Only 6.15 to 8.62 per cent seed set was observed when pollinations from different restorer lines were done 6 hrs after the collection of pollens. It was only 1.57 to 7.70 per cent when pollinations were effected 8 hrs after the collection of pollens.

In this season (summer), amongst the different restorer lines, the highest per cent seed set was observed when the pollinations were effected by utilizing pollens of PD 3-1-11 (37.48 %), while it was the lowest in 168(32.05 %). Next to PD 3-1-11 the restorer IS-84 also showed (35.01 %) good seed setting . Amongst the different restorer lines, PD 3-1-11 was significantly superior to the rest of the restorer lines. Even when pollinations were effected 8 hrs after the collection of pollen, 7.70 per cent seed set was observed in this line. The seed setting for the same period was 5.28, 5.23, 2.72 and 1.57 per cent in IS-84, CS-3541, 168 and Swarna, respectively.

On the mean performance basis over different pollination periods PD 3-1-11 showed significantly highest seed setting as compared to the rest of the restorer lines. Similarly, all the lines showed good (59.39 to 69.26 %) seed setting in respect of pollinations effected upto 2 hrs.

Thus, it could be seen that the highest per cent seed setting (65.89 to 72.07 %) was observed in the case of immediate pollination, (i.e. pollinations effected immediately after anthesis) while reasonably good seed setting was observed when earheads were pollinated 2 hrs after anthesis (56.73 to 61.75 %) and the least seed setting was observed when pollinations were effected 8 hrs after the collection of pollens (1.57 to 7.70 %).

Table 9. Mean percentage of seed setting in male sterile lines when pollinated at different hours after collection of pollens from restorer lines (Pollen viability) Summer-84,

Sr. No.	Restorer lines	Pollination period in hours					Mean
		Immediate	2 hours	4 hours	6 hours	8 hours	
1.	IS-84	71.26 (88.67)	59.08 (73.62)	33.05 (29.67)	6.42 (1.32)	5.28 (0.89)	35.01
2.	CS-3541	67.54 (85.40)	56.73 (70.09)	31.25 (26.92)	8.29 (2.18)	5.23 (0.87)	33.80
3.	168	65.89 (83.32)	60.40 (75.62)	25.10 (18.04)	6.15 (1.25)	2.72 (0.29)	32.05
4.	Swarna	69.54 (87.84)	59.02 (73.54)	31.81 (27.77)	7.25 (1.62)	1.57 (0.06)	33.83
5.	PD-3-1-11	72.07 (30.54)	61.75 (77.62)	37.28 (36.72)	8.62 (2.29)	7.70 (1.80)	37.48
	Mean	69.26	59.39	31.69	7.34	4.50	

(Figures in parentheses are original figures)

	S.E.±	C.D.at 5%
Restorer lines	0.50	1.45
Pollination period	0.50	1.45
Restorer lines x Pollination period (Interaction)	1.11	3.26

In general, in the kharif season longer pollen viability was observed followed by the rabi and summer seasons for all the pollination periods. In all the seasons, nearly 50 per cent seed setting was observed when pollinations were effected upto 4 hours after the collection of pollens. Seed setting was relatively higher when pollinated with PD 3-1-11, 168 and CS-3541 in kharif , PD 3-1-11, CS-3541 and IS-84 in rabi and PD 3-1-11, IS-84 and Swarna in the summer season. In the case of swarna, low seed setting was observed in kharif and rabi, while in 168 it was low only in summer. In kharif the lowest seed set was observed when pollinated with CS-3541 (48.20 %) indicating its sensetivity to temperatures and relative humidity. The highest seed setting was noticed in PD 3-1-11 for the kharif (51.94 %), rabi (47.67 %) and summer (37.48 %) seasons.

In all the seasons, rapid reduction in seed setting was noticed when pollinations were effected 6 hours after the collection of pollens. The rate of reduction was very rapid in summer followed by rabi and kharif indicating probable role of temperatures and humidity. In all the seasons when pollinations were effected after 8 hrs of the collection of pollens, the highest seed setting was noticed for the variety PD 3-1-11 (25.28 %, 22.42 % and 7.70 %) and it was low in CS-3541(22.71%), 168 (17.76 %) and Swarna (1.57%) in the kharif and rabi and summer seasons, respectively.

In general, the results revealed that in all the seasons maximum seed setting was observed in PD 3-1-11 i.e. 51.94 per cent, 47.64 per cent and 37.48 per cent in kharif, rabi and summer seasons, respectively. While, it was the least in CS-3541 i.e. 48.20 per cent in the kharif and in 168 i.e. 44.10 and 32.05 per cent in rabi and summer seasons, respectively.

4.3 Temperature effect

Within the different temperature ranges occuring during the kharif, rabi and summer seasons, differential as in various male sterile and restorer lines was observed.

4.3.1 Kharif

In kharif , the early blooming was observed in male-steriles like CK-60A , 2219A(58 days and 55 days, respectively). Whereas in 2077A, 296A and 36 A, blooming started after 71 days, 66 days, 67 days, respectively. The range of maximum and minimum temperatures was 28.8 to 33.5°C and 21.0 to 23.5°C, respectively in this season with relative humidity range of 81 to 97 % in this season. In respect of restorer lines, early blooming was observed in IS-84, PD 3-1-11 (61 days each) and in Swarna (55 days) whereas delayed blooming was observed in CS-3541 (67 days) and 168 (69 days), at the above temperature and humidity regimes.

Table 10. Temperature and relative humidity effect on blooming

Season	Temperature range		Relative humidity %	Male sterile lines (days to flower)					Restorer lines (days to flower)				
	Maximum °C	Minimum °C		CK-60A	2077A	2219A	296A	36A	IS-84	CS-3541	Swarna	168	PD-3-1-11
Kharif	28.8 to 33.5	21.0 to 23.5	81 to 97	58	71	55	66	67	61	61	55	69	61
Rabi	27.4 to 32.5	12.5 to 22.0	69 to 92	79 (21)	87 (16)	79 (24)	85 (19)	83 (16)	81 (20)	87 (20)	80 (25)	85 (16)	81 (20)
Summer	37.8 to 41.7	17.8 to 27.0	29 to 79	61 (3)	78 (7)	60 (5)	68 (2)	66 (-1)	62 (1)	76 (9)	60 (5)	74 (5)	63 (2)

Figures in parenthesis indicate delay in flowering compared to kharif season.

4.3.2 Rabi

In rabi, the early blooming was observed in male-steriles like CK-60A , 2219 A (79 days). Whereas, in 2077 A (87 days), 296 A (85 days) and 36 A(83 days), delayed flowering was observed. The range of maximum and minimum temperatures was 27.4 to 32.2°C and 12.5 to 22.0°C, respectively. The relative humidity ranged from 69 to 92 % in this season. In respect of restorer lines the early blooming was observed in IS-84, PD 3-1-11 (81 days) and Swarna (80 days), whereas delayed blooming was observed in CS-3541 (87 days) and 168 (85 days) at the above temperature and humidity regiumes.

4.3.3 Summer

In summer, the early blooming was observed in male-steriles like CK-60A (61 days) and 2219 A (60 days), whereas delayed blooming was observed in 2077 A (78 days), 296 A (68 days) and 36 A (66 days). During this season, the range of maximum and minimum temperatures was 37.8 to 41.7°C and 17.8 to 27.0°C, respectively. The relative humidity ranged from 29 to 79 % in this sesason. In respect of restorer lines, the early blooming was observed in IS-84 (62 days), PD 3-1-11 (63 days and Swarna (60 days), whereas the delayed blooming was observed in CS-3541 (76 days) and 168 (74 days) at the above temperature and humidity regiumes.

In the kharif, rabi and summer seasons, the early blooming was observed in CK-60A and 2219 A, whereas the delayed blooming was observed in 2077 A, 296 A and 36 A. In the case of restorer

lines, the early blooming was observed in IS-84, PD 3-1-11 and Swarna and the delayed flowering was observed in CS-3541 and 168. Thus, it appears that early and late blooming varieties behaves more or less in a similar way in different seasons.

In general, the flowering was delayed considerably in the rabi season. During this season maximum and minimum temperatures were low and relative humidity was also low, which probably affected the growth rate and delayed flowering. The lateness as compared to the kharif season was from 16 to 24 days in male steriles and 20 to 25 days in restorer lines.

During the summer season, the minimum and maximum temperatures were high while relative humidity was low. This situation also delayed flowering but the differences as compared to kharif were low. The male-sterile lines flowered late by 2 to 7 days and restorer by 2 to 9 days. The summer planting was delayed (24-3-83) and flowering of the crop took place in the last week of May to the first fortnight of June, when temperatures had started declining. This could also be the reason for narrow differences in flowering as compared to kharif.

5. DISCUSSION

5. DISCUSSION

In sorghum, hybrid seed production is a highly technical job and it also involves high monetary investment. The hybrid seed production in this crop has become feasible mainly due to the development of dependable male-sterile lines which solely depend on their male parent for pollen supply. Under this situation nicking of male and female lines is very vital for proper seed setting. Many times, due to the differential environmental interactions, the behaviour of male and female lines varies from season to season. Similarly, the period of receptivity and pollen viability also differs in different seasons. It is, therefore, very essential to have knowledge of flowering behaviours of different parents involved in the released hybrids, so that successful seed production of these hybrids could be undertaken in different seasons.

5.1 ANOVA as whole

5.1.1 Stigma receptivity

The results of the analysis of variance for stigma receptivity have been presented in Table 2 and figures 1. The results indicated significant differences for the receptivity of stigma in all the seasons, indicating significant variation for this trait among the different male sterile lines. The variation due to starvation period Vs M.S. lines was significant which indicates the differential starvation period amongst the lines. The earlier findings of Atkins (1971) are in agreement with this observation.

In the kharif season, the stigma receptivity period in M.S. line 2219 A was longer i.e. 13 days after stigma emergence, whereas it was 11 days in the rest of the male-sterile lines i.e. in CK-60A, 2077A, 36A, and 296 A. Chopade et al. (1973) and Singh et al. (1979) also reported 10 days' stigma receptivity period in CK-60A , 2077A and 36A during the kharif season (Harlan 1944-45) reported 13 days stigma receptivity period in buffalo-grasses in the kharif season.

In rabi, M.S. line 2219 A showed longer stigma receptivity (13 days) followed by 296A (11 days), 2077 A and 36 A (9 days), while only 7 days stigma receptivity was noticed in CK-60A. Similar results were observed by Singh et al. in kharif for M.S.lines like CK-60A and 2077A (1979). However, in 36A they observed only 6 days stigma receptivity period in this season and this may be attributed to low temperature and relative humidity. The earlier findings of Charles et al. (1956) and Stephens (1934) are in agreement with these investigations. They reported that in cooler temperatures stigma receptivity lasts for longer time.

Ross (1957) reported 10 days' stigma receptivity in combine Kafir-60 (BC_1) and Martin (BC_3). Mahudeswarn (1960) also reported 10 days' stigma receptivity after protrusion in M.S. line 355 A.

Manoliu et al.(1965-67) also reported 7-8 days' stigma receptivity in A-85, A-86 and 9-10 days in A-72. However, Bapat et al.(1967-68) and Konovalav(1969) reported 14-15 days'

stigma receptivity in M.S. line CK-60A. These findings are more or less in agreement with the results reported in this dissertation.

In the summer season, stigma receptivity ranged from 5 to 11 days, being longer in 2219 A (11 days) followed by CK-60A, 2077 A, and 296 A (9 days). However, in 36A the stigma receptivity period was very short during this season (5-6 days). The low stigma receptivity period could be attributed to high temperature (37.8 to 41.7°C) and low humidity (29 to 79 %) conditions. Amongst the females only CK-60A and 36 A showed shorter span of six to seven days' stigma receptivity in the summer season as compared to the rest of the M.S. lines of which receptivity ranged from 7 to 13 days. Hence, care need to be taken while planning seed production of hybrids CSH-1, CSH-7R and CSH-8R where these M.S. lines are involved. It is necessary to plant male and female lines in such a way that abundant pollen is available during stigma receptivity period.

Lnnik and Yastreber (1969) reported 17-24 days' stigma receptivity period in grain sorghum in the kharif season.

Stephens (1934) reported that in Balckhull Kafir stigma receptivity remained for longer period of 16 days after blooming in cool weather. Charles et al. (1956) also reported that stigma receptivity was longer at lower temperature than at high temperatures.

In general, in all the male-sterile lines stigma remained receptive for 11 to 13 days in kharif and 7 to 13 days in rabi. Under this situation even if flowering of male parents is delayed as compared to the male-sterile lines, by 2-4 days, seed setting will be more or less normal. In the summer season, only 5 to 11 days' stigma receptivity period was noticed. This shorter period of receptivity in all the M.S. lines in this season could be due to high temperatures (37.8 to 41.7°C) and low humidity (29 to 79%) conditions.

The M.S. line 2219 A has showed better receptivity as compared to the rest of the lines in all the seasons indicating its stability. This line could form a good source to developing new stable M.S. lines.

5.1.2 Pollen viability

The results of the analysis of variance for pollen viability have been presented in table 6 and figure 2. Significant differences were observed for pollen viability in different restorer lines under study.

In kharif, significantly higher seed setting was observed (71.34 to 77.47 %, $\bar{X}$ = 73.92 %), when the pollinations were effected immediately and 2 hours after the collection of pollens. The seed setting was reduced significantly after each pollination period. However, fairly good seed setting (49.95 %) was observed at 4 hours' pollination period. This indicates that for successful seed production pollination should be effected within 2 hours after the opening of flowers or collection of pollens.

Amongst the restorer lines, seed setting was significantly higher when pollinated with PD 3-1-11 (77.47 %) and Swarna (75.68 %) as compared to the rest of the 'R' lines, in the case of pollinations effected immediately after the collection of pollens and the seed setting was 70.09 and 70.41 per cent respectively, when pollinations were effected 2 hrs after collection of pollens. Significantly highest seed setting was observed when pollinations of 168 were effected 4 hrs and 6 hrs after the collection of pollen, while significantly lowest seed setting was observed in Swarna when pollinations were affected 4 hrs and 6 hrs after the collection of pollens.

Thus, this indicates that for effective seed setting pollinations within 2 hrs after the collection of pollens is more effective than the pollinations affected thereafter. The earlier findings of Stephens and Quinby (1934), Bapat et al. (1967-68) are in agreement with these observations.

In rabi, significantly highest seed setting was observed when the pollinations were effected immediately (68.70 to 73.94 %, $\bar{X}$ = 70.43%) and 2 hrs (60.22 to 67.94%) $\bar{X}$ = 62.43 %) after the collection of pollens. The seed setting was reduced significantly after each pollination period. However, fairly good seed setting (45.9 %) was observed at 4 hrs of the pollination period. This indicates that for successful seed production, pollinations should be effected within 2 hrs after the opening of flowers or collection of pollens.

Amongst the restorer lines seed setting was significantly higher when pollinated with PD 3-1-11 (73.94 %) and 67.94 %) and Swarna (71.01 % and 61.18 %) as compared to the rest of the restorer lines in the case of pollinations effected immediately and 2 hrs after the collection of pollens respectively, significantly highest seed setting was observed when pollinations of CS-3541 (51.83 %) were effected 4 hrs after the collection of pollens, while significantly lowest seed setting was observed in Swarna (42.38 %) when pollinations were effected 4 hrs after the collection of pollens. Thereafter, drastic reduction in per cent seed setting was observed.

Thus, this indicates that the in kharif and rabi seasons for effective seed setting pollinations within 2 hrs after the collection of pollens, are more effective than the pollinations effected thereafter. In summer, significantly highest seed setting was observed when the pollinations were effected immediately (65.89 to 72.07 %, $\bar{X}$ = 69.26 %) and 2 hrs (56.73 to 61.75 %, $\bar{X}$ = 59.39 %) after the collection of pollens, after which seed setting was reduced significantly for each pollination period. This indicates that for successful seed production in summer, pollinations should be effected within 2 hrs after the collection of pollens or after opening of flower.

Amongst the restorer lines, seed setting was significantly higher when pollinated with PD 3-1-11 (72.07 %) and IS-84(71.26%) as compared to the rest of the 'R' lines, in the case of

pollinations effected immediately after the collection of pollens. Significantly highest seed setting was observed when pollinations of PD 3-1-11 were effected 2 hrs(61.75%) after the collection of pollens, while it was low in CS-3541 (56.73 %) for the same pollination period. Thereafter in all 'R' lines drastic reduction in per cent seed setting was observed and pollens lost their viability very rapidly. Shorter period of pollen viability, i.e. upto 2 hrs in this season, was attributed to high temperature (37.8 to 41.7^{o}C) and low humidity (29 to 79%). Harrison and Futton(1934) reported cotton pollens stored in dessicator at air temperature over calcium chloride failed to effect fertilization. Pope (1939) also observed that cotton pollens at 36^{o}F still produce seed but at 40^{o}F there is complete failure of seed setting and these findings are in agreement with the present investigation.

This has broadly brought out indicates that for effective seed setting pollination upto 2 hrs after the collection of pollens is more effective in all the three seasons than the pollinations effected thereafter.

In general, in the kharif season longer pollen viability was noticed in IS-84, CS-3541, 168 and PD 3-1-11 i.e. upto 4 hours, whereas in Swarna, pollens remained viable only for 2 hrs after the collection of pollens. In rabi longer pollen viability was observed in IS-84, CS-3541 and PD 3-1-11 i.e. upto 4 hours, while, in 168 and Swarna pollens remained viable

only upto 2 hrs in this season. Whereas in the summer season, in all the restorer lines, pollens remained viable only 2 hours after the collection. These findings are in agreement with the results of Bapat et al. (1967-68) in sorghum and Quinbey(1934) in Barley crop.

This study has clearly brought out the stability of restorer line PD 3-1-11 in all the seasons. This could be due to its inherant ability to sustain to varying temperature and humidity conditions and also to its ability to produce profuse pollens.

5.3 Temperature effect

Differential blooming in various male sterile and restorer lines was observed during kharif, rabi and summer season.

During kharif season maximum and minimum temperature range was 28.8 to 32.5°C and 21.0 to 23.5°C respectively with relative humidity of 81 to 97 %. For these temperatures and humidity regimes early blooming was observed in CK-60A (58 days) and 2219A (55 days), whereas in 2077A (71 days), 36A (67 days) and 296A (66 days) delayed blooming was observed. In restorer lines early blooming was observed in IS-84, PD 3-1-11 (61 days for both) and Swarna (55 days), whereas in CS-3541 and 168 delayed blooming was noticed i.e. 67 days and 69 days respectively for same temperature and humidity levels.

Miller, et al.(1968) concluded that the photoperiodic effect is apparent only if the nights are to short to allow the synthesis of auxin, to allow early floral initiation.

Caddel and Weibel (1971) also found that day temperatures were more important in determining length of panicle development than the time needed to reach floral initiation and these findings are in agreement with the present investigation.

In rabi season delayed blooming was observed in all the male sterile and restorer lines. In this season early blooming was observed in CK-60A and 2219 A(79 days) where as in 2077A, 296A, and 36A blooming was observed after 87 days, 85 days and 83 days, respectively. The maximum and minimum temperature range was 27.4 to 32.5 ^{o}C and 12.5 to 22.0^{o}C with 69 to 52 % relative humidity. In case of restorer lines early blooming was observed in IS-84, PD 3-1-11 (81 days each) and Swarna (80 days), whereas late blooming was noticed in CS-3541(87 days) and 168 (85 days) for same temperature and humidity regimes.

Sieglinger (1936) reported a sorghum plant continuse to produce leaves in the meristem until a floral bud is initiated and the production of an additional leaf delays flowering by about 3 days.

Thus it could be seen that the both the male sterile and restorer lines appeared to be thermosensitive and pattern of delayed flowering was uniform in all the lines in both the season. The earlier findings of Hammer (1940) are in agreement with this investigation.

In the summer season, the early blooming was observed in CK-60 (61 days) and 2219 A(60 days), whereas blooming period was 78 days, 68 days and 66 days in 2077 A, 296A and 36A, respectively. In this season, maximum and minimum temperature range was 37.8 to 41.7^{o}C and 17.8 to 27.0^{o}C with to 73 % relative humidity. The restorer lines IS-84 and Swarna bloomed early i.e. after 62 to 60 days, respectively. However, blooming period in CS-3541, 168 and PD 3-1-11 was 76 days, 74 days and 73 days, respectively for the same temperature and humidity level. In this season all the male steriles behaved like the kharif and rabi seasons, while the restorer line PD 3-1-11 behaved differently in this season as compared to the earlier seasons. Thus indicating differential response of PD 3-1-11 to higher temperature and low humidity conditions.

In general, it is interesting to note that the early parents flower early in all the seasons, though period may vary in different seasons. Flowering of male and female lines was delayed by 16 to 24 days in the rabi and 2 to 9 days in the summer season.

6. SUMMARY AND CONCLUSION

6. SUMMARY AND CONCLUSION

In hybrid seed production of sorghum, it is very essential to know the flowering behaviour of male-sterile and restorer lines, so that appropriate steps could be taken to manipulate nicking of male and female lines. Similarly, for successful manipulation of flowering of parental lines, high level of management is a must. Seed setting in sorghum hybrids where male sterile lines have been used as female lines was ultimately depend on proper nicking of male and female lines included in seed production. Hence, studies in respect of stigma receptivity and pollen viability will help the seed producing organisations to suitably manipulate dates of sowing of the parents of released hybrids for their proper nicking to get good seed yield. With this view, five sorghum male-sterile lines viz. CK-60A, 2077A, 2219A, 296A and 36A and five restorer lines viz. IS-84, CS-3541, 168, Swarna and PD 3-1-11 were included in the present investigation to study their stigma receptivity and pollen viability during the summer 1983, kharif 1983 and rabi 1983-84 seasons.

6.1 Stigma receptivity

Stigma receptivity studies revealed that in kharif longer stigma receptivity was observed in 2219A (13 days), while it was 11 days in the rest of the male sterile lines. In rabi also, 2219 A exhibited longer stigma receptivity (13 days) followed by 296A (11 days), 36A and 2077A (9 days each). Stigma receptivity was very short in CK-60A(7 days) in this season.

In summer 11 days' stigma receptivity was noticed in 2219A, followed by 9 days in CK-60A, 2077A and 296A, whereas in 36A, stigma remained receptive upto 7 days only.

In general, stigma receptivity studies revealed that in all the male sterile lines stigmas remained receptive for 11 to 13 days in kharif, 7 to 13 days in rabi and 5-11 days in the summer season. These findings indicate that even if male parent, flowers 5-7 days late, the seed setting will not be affected significantly as fairly good seed setting was observed upto 5th days of starvation period (i.e. 9 days after stigma emergence).

6.2. Pollen viability

Pollen viability studies revealed that in kharif longer viability period i.e. 4 hours was observed in all the restorer lines excepting swarna where it was only 2 hours. In rabi 4 hours, viability period was noticed in IS-84, CS-3541 and PD 3-1-11 followed by 2 hours in 168 and Swarna. In summer pollens remained viable only for 2 hrs in all the restorer lines. This shorter period of viability in all the restorer lines in this season could be due to high-temperature (37.8 to 41.7°C) and low humidity (29 to 79%) conditions.

In general, pollen viability studies revealed that pollens from all the restorer lines remain viable for 2-4 hours in the kharif and rabi seasons, while the viability of only 2 hours was noticed in all the restorer lines during summer.

6.3. Temperature and humidity effect

In all the seasons differential blooming in all the male sterile and restorer lines was observed. In kharif early blooming was observed in M.S. lines viz. CK-60A(58 days) and 2219 A(55 days) and restorer lines viz. IS-84, PD 3-1-11(61 days for both) and Swarna (55 days). Whereas, delayed blooming was noticed in the case of females like 2077A (71 days), 36A (67 days) and 296A (66 days) and restorers like CS-3541 and 168 (67 and 69 days respectively) for the temperature range of 28.8 to 33.5°C and 21.0 to 23.5°C respectively with relative humidity of 81 to 97 %.

In the rabi season delayed blooming was observed in all the male sterile and restorer lines compared to kharif season. Early blooming was observed in CK-60A and 2219A (79 days), whereas in 2077A, 296A and 36A the blooming period was 87 days, 85 days and 83 days, respectively. In the case of restorer lines the early blooming was observed in IS-84, PD 3-1-11(81 days both) and Swarna (80 days), whereas the late blooming was noticed in CS-3541 (87 days) and 168 (85 days) for maximum and minimum temperature ranged 27.4 to 32.5°C and 12.5 to 22.0°C respectively with relative humidity 69 to 92 %.

In the summer season, the early blooming was observed in M.S. lines viz. CK-60A (61 days) and 2219 A(60 days) and restorer lines viz. IS-84 (62 days) and Swarna (60 days). Whereas the delayed blooming was noticed in 2077A (78 days), 296A (68 days) and 36A (66 days) and it was 76 days, 74 days and 73 days in restorer lines like CS-3541, 168, PD 3-1-11,

respectively for the maximum and minimum temperature range of 37.8 to 41.7°C and 17.8 to 27.0°c respectively with 29 to 73 % relative humidity.

Thus, it could be seen that both male sterile and restorer lines appeared to be thermosensitive and the pattern of delayed early flowering was uniform in all the lines studied in different seasons.

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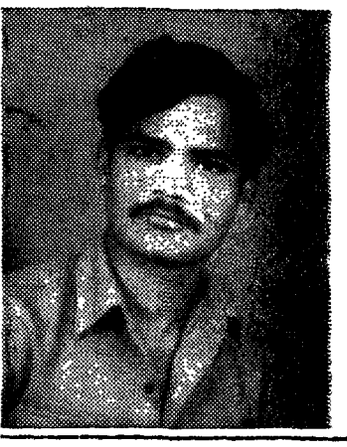
8. VITA



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