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Flowering and Fruiting of Tomatoes (*Lycopersicon esculentum* Mill.) in Qassim, Saudi Arabia during Summer

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Abstract. The tomato cultivar "Pearson Al-improved" was planted on three different dates starting January 1987 and 1988 with monthly intervals, to define the reproductive attributes and abnormalities implicated in the low fruit yield of field-grown tomato usually encountered in Qassim, Saudi Arabia, during summer. The total fruit yield declined significantly with delay in planting and progress of summer. This was brought about, primarily, by the significant decline in both fruit set and average fruit weight in February planting, in addition to the reduction in the number of flowers produced in March planting. The failure of fruit set in February planting was mainly due to the lack of pollination resulting from anther indehiscence and stigma exsertion, and was due to the failure of fertilization and, probably, embryo abortion in March planting. The failure of fertilization could be attributed to anther indehiscence, low pollen production and viability, stigma exsertion and low ovule viability. The decline in average fruit weight was, apparently, due to the decline in number of seeds per fruit and this, in turn, could be attributed to the same forementioned abnormalities responsible for fruit set failure. The high temperature prevailing during flowering was apparently the most important climatic factor inducing these abnormalities encountered at late plantings. Therefore, heat tolerant genotypes may be used to develop cvs suitable for summer conditions in Qassim.

Introduction

Tomato production in Qassim, during the summer season is limited to air-cooled greenhouses due to the severe decline in fruit yield of field-grown plants [1,2]. The yield component mostly affected is the number of fruits per plant [1]. Despite its obvious importance, no further studies were performed to investigate this problem.

Under optimal management conditions, the number of fruits in tomato is controlled by the number of flowers produced and/or fruit set. The failure of fruit set, under such conditions, would result from one or more of many reproductive abnormalities; depending on the levels of temperature [3,4], irradiance [5,6] and relative humidity [7]; at flowering stage.

This paper reports the results of experiments designated to study the reproductive attributes and abnormalities responsible for the low fruit yields of field grown tomatoes encountered in Qassim, Saudi Arabia, during the summer season.

Materials and Methods

The tomato cultivar "Pearson Al-improved", which is widely spread in Qassim region was grown at the College of Agriculture, Buriedah, Qassim, Saudi Arabia during 1987 and 1988. Seeds were sown in small plastic containers filled with sterilized mixture of 1 peat : 2 sandy loam soil, by volume, and watered daily. At the fourth true leaf stage, uniform seedlings were transplanted each to a plastic pot filled with an alkaline sandy loam soil containing 86.6% sand, 0.4% silt and 13.0 clay. Plants were irrigated whenever the tensiometers, placed in the pots, indicated 20 kPa. Half strength Hoagland's nutrient solution was used alternately with tap water. Mean daily air temperatures, solar radiation and average relative humidity were obtained from a nearby meteorological facility.

Experiment 1

The seeds were sown at three different dates starting January 12th. and 28th., with monthly intervals, in 1987 and 1988, respectively. The seedlings were transplanted each to a 40-liter plastic pot. The pots were arranged in a randomized complete block design with three replications. Each replication was represented by two pots, one of which was used for destructive analysis.

The date at which each plant had the first open flower was recorded to calculate the number of days from sowing to anthesis of the first flower. Using 5 clusters [2-6] per plant, open flowers were counted and examined for stigma exsertion beyond the staminal cone by more than 2mm to calculate the percent flowers with exserted stigmas. In addition, some open flowers were collected at mid-day, then pistils were removed and each one was put on a glass slide in a few drops of aniline blue. A cover slip was put on each slide and pressed gentley to crush the tissues. The slides were then examined with a light microscope and the percentages of flowers with pollen free stigmas were determined. In addition, staminal cones of these flowers were examined with a dissecting microscope to estimate the percentage of flowers with abnormal anthers.

In 1987, some pollen grains were collected from three open flowers per plant in the morning. Pollen grains of each plant were put on a glass slide in a few drops of acetocarmine. After twenty minutes a cover slip was placed on the slide and then three microscopic fields were examined with a light microscope to determine pollen viability. The viable pollen grains would stain deep red, whereas the non-viable pollen would not stain. In 1988, pollen viability was determined by in vitro germination. Few drops of a medium composed of 5% sucrose in 100 ppm boric acid solution [8] were put on each slide. Then some pollen grains, collected as described earlier, were transferred to the slides. Each slide was put in a petri dish on a wet filter paper. The petri dishes were covered with wet blotting papers and put in a growth chamber at 25

± 2°C and 80-90% R.H. Drops of the medium were frequently added to the slides for replenishment. After five hours, a cover slip was put on each slide. Then, number of total pollen grains and those with pollen tubes in excess of 30 μm were counted in three microscopic fields per slide, using a light microscope provided with a caliberated ocular micrometer, to determine pollen viability (100 × number of pollen grain with tubes/total number of pollen grains).

To determine weight of pollen grains per flower, some staminal cones were weighed with and without pollen grains one day perior to anthesis.

Open flowers of five clusters [2-6] per plant and the fruits developed from them were counted, and fruit set percentage was calculated (100 × number of fruits/ number of flowers which reached anthesis). Then each fruit was picked when started to change red and weighed to determine average and total fruit weight.

Percentages were transformed to arc sine [9], then all data were subjected to analysis of variance.

Experiment 2

All specifications in this experiment, which was executed during 1988, were as described in Experiment 1; except that two additional plants per each planting data were grown in a greenhouse, kept at 18-25°C air temperature and 50 - 80% relative humidity.

At anthesis, 20 open flowers on one plant were tagged and left to set fruit naturally. These would be referred to as control. Another 20 similar flowers on the other plant were tagged and artificially (hand) pollinated using pollen from the plants which were grown in the greenhouse. One month later the percent of fruit set was determined to be used as an estimate for ovule viability.

The data were subjected to arc sine transformation [9] and analysed as split plot using planting dates as main treatments and pollination methods as subtreatments.

Results

Day and night air temperatures and solar radiation during the experimental periods were minimal in January, then increased gradually to reach the maximum levels in June or July (Fig. 1). Conversely, the relative humidity was maximum in January, then decreased progressively to reach the minimum in July and August in 1987 and 1988, respectively.

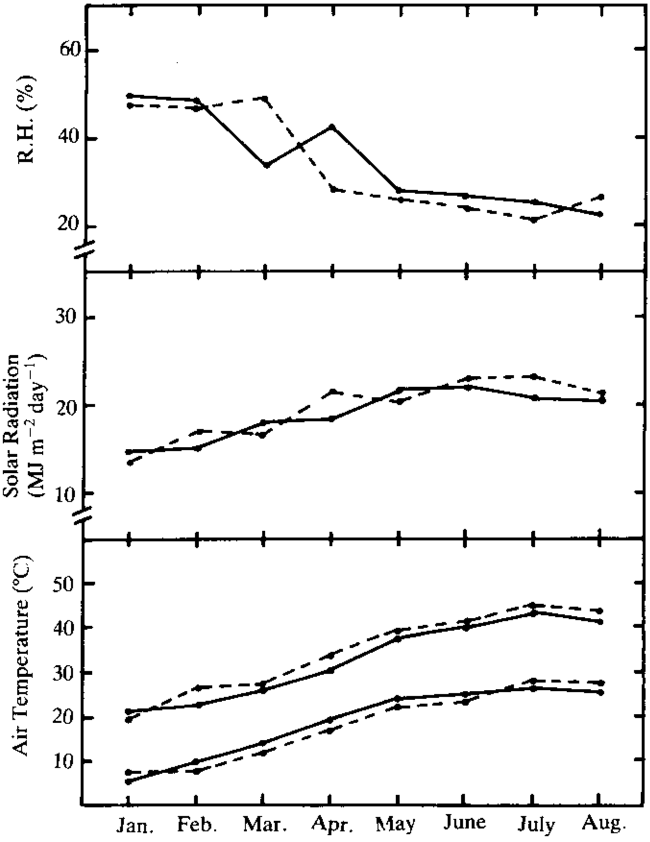

Fig. 1. Mean daily minimum and maximum air temperature, solar radiation and average relative humidity during 1987 (•-------•) and 1988 (•———•) experimental periods.

Experiment 1

The delay in planting date resulted in earlier anthesis of the first flower during both years (Table 1). However, the differences were not statistically significant at the 5% level except in March planting of 1987.

Examining flowers at anthesis showed that none or few stigmas had exserted beyond the staminal cones in the first planting (Table 1). The percentages of exserted stigmas increased significantly with the delay of planting. Most of the fixed exserted

Table 1. Days to anthesis and floral characteristics of cv. "Pearson Al-improved" planted on three different dates during 1987 and 1988.

Planting date	Days to anthesis	Exserted stigmas (%)	Pollen free stigmas (%)	Indehiscent anthers (%)	Viable pollen grains (%)	Weight of pollen grains per flower (%)
1987						
January	70 a[1]	0.0 a	6.7 a	5.0 a	91.2 a	7.3
February	66 ab	10.3 b	38.3 b	46.7 b	54.8 b	5.4
March	63 b	18.8 c	61.7 c	76.7 c	19.2 c	V. low
1988						
January	66 a	2.2 a	3.7 a	3.7 a	52.5 a	8.1
February	68 a	13.3 b	46.3 b	50.0 b	33.8 b	4.9
March	64 a	26.7 c	72.2 c	77.8 c	9.5 c	V. low

1 : Means in the same column having the same letter are not significantly different at 5% level, by Duncan's multiple range test.

stigmas were devoid of pollen grains. Of all the flowers examined in the first planting few had no pollen grains on their stigmatic surfaces (Table 1). The percentages of such flowers increased substantially to reach more than 60% in the last planting. The differences among the planting dates were statistically significant at the 5% level.

Most of the open flowers produced in the first planting were with normal anthers, whereas the plants grown afterwards produced significantly higher percentages of indehiscent anthers (Table 1). These indehiscent anthers were shrivelled and had very narrow longitudinal slits. They contained mainly inviable pollen grains as detected by staining with acetocarmine. Although the data of the staining and in vitro germination techniques differed greatly, both methods showed that pollen viability declined significantly with the delay in planting date (Table 1). Viable pollen grains were round and about 20 μm in diameter, whereas the inviable ones were smaller, irregular and had shrunken cytoplasmic contents. The weight of pollen grains per flower followed the same trend as pollen viability with the anthers produced in the last planting being almost empty (Table 1).

Number of flowers produced per plant declined progressively with the delay in planting (Table 2). The reduction in February planting was statistically insignificant, whereas the reduction in March planting was significant at the 5% level, in comparison with the other two plantings. About 65% of the flowers produced in January planting developed into fruits, compared with 33% and 10% in February and March plantings, respectively (Table 2). The three plantings differed significantly from each other with respect to both the number of fruits and the percentage of fruit set at the 5% level. The fruits produced in January planting were the largest, whereas those

Table 2. Fruit yield and its components of cv. "Pearson Al-improved" planted on three different dates, during 1987 and 1988.

Planting date	No. of flowers	No. of fruits	Fruit set (%)	Average fruit weight (g)	Fruit weight per plant (kg)
1987					
January	29 a[1]	19 a	66.1 a	96.3 a	1,855 a
February	27 a	10 b	35.5 b	64.7 b	0.622 b
March	21 b	3 c	12.7 c	25.3 c	0.068 c
1988					
January	28 a	18 a	63.7 a	101.7 a	1.771 a
February	26 a	8 b	30.3 b	60.7 b	0.484 b
March	20 b	2 c	9.9 c	28.3 c	0.057 c

1 : As in Table 1.

produced in March planting were the smallest (Table 2). A similar trend was also reflected by the average fruit weight per plant.

Experiment 2

Artificial pollination, using pollen grains of which above 70% were viable, as detected by staining with acetocarmine, raised fruit set percentage signficantly, in comparison with the control, in both January and February plantings (Table 3). In March planting, although there was some increase, the difference was not statistically significant at the 5% level. Conversely, the differences in fruit set percentage detected between January and February plantings were insignificant. However, in March planting the percentage of fruit set was significantly less than those of the other two plantings, irrespective of pollination method (Table 3).

Table 3. Fruit set percentages in naturally (control) and artificially (hand) pollinated flowers in cv. "Pearson Al-improved" during 1988.

Planting date	Control	Artificial (hand) pollination	Level of Significance[1]
January	68.3 a[2]	90.0 a	**
February	36.7 b	88.3 a	**
March	16.7 c	18.3 b	NS

1 : ** Indicates significant at 1% level, NS not significant at 5% level.

2 : Means in the same column having the same letter are not significantly different at 5% level, by Duncan's multiple range test using transformed values (arc sine).

Discussion

Based on the performance of five clusters [2-6] per plant, the progressive decline in tomato fruit yields, with the delay in planting, could be attributed to the decline in the number of fruits and the average fruit weight (Table 2). On the other hand, the decline in the number of fruits was mainly brought about by the decline in fruit set percentage in February planting; and by the decline in number of flowers and fruit set percentage in March planting.

The reduction in the number of flowers in March planting was apparently due to the high temperature prevailing at flowering as stated by many workers [4, 10-13]. Such a high temperature could have resulted in carbohydrate deficiency [6] and consequently the significant reduction in the number of flowers produced.

The results of Tables (1 and 3) revealed that the failure of fruit set, in February planting, was related to male sterility, in addition to poor ovule viability and, probably, embryo abortion in March planting.

Working with tomato plants grown under high temperature, Rylski [13] demonstrated that all non-fertilized flowers had aborted. In the present study, all the flowers with pollen free stigmas (Table 1) were not fertilized and, therefore failed to set fruits. Lack of pollen grains on the stigmas of these flowers was primarily due to anther indehiscence and stigma exsertion in February planting, in addition to low pollen production in March planting. Moreover, if it was not for these factors, failure of fertilization would also be induced by poor ovule viability in March planting.

Not only flowers with pollen free stigmas but also some of the pollinated flowers abscised (Tables 1,2). In February planting, perhaps these flowers did not have enough pollen grains on their stigmas to affect fertilization, as a result of the complete or partial anther indehiscence, whereas in March planting, pollen scarcity, poor pollen and ovule viability could be responsible for the failure of fertilization of such flowers.

Anther indehiscence was reported with other tomato cvs grown under high temperature regimes [3,4,14] and it has been ascribed to abnormal development of the endothecium layer [14]. Likewise, stigma exsertion, a direct cause of flower drop [15], low pollen viability and production [3,4], low ovule viability [4] and embryo abortion [16] were also reported to be induced by high temperature.

A positive correlation was reported between number of seeds per fruit and average fruit size [17,18], especially under high temperature level [13]. Thus the reduction in average fruit weight with the delay in planting, observed in this study, was apparently due to the reduction in the number of seeds per fruit. Failure of seed set could be attributed to the same abnormalities as with fruit set. Such a reduction in the average fruit weight was also reported with other tomato cvs grown under high temperature and light intensity [19].

This study showed that in Qassim, Saudi Arabia, tomato production at early summer could be increased by using some measures which inhance pollination efficiency such as flower vibration. The resemblance between the results of this and of the other studies conducted under high temperatures [3,4,11,12,14,17] indicated that the high temperature was the most influencial climatic factor. Therefore cvs which exhibited low anther indehiscence such as "Saladette" [14] and no stigma exsertion such as "VF-36" [14], at high temperature, should be used in breeding programs to develop tomato cvs suitable for early summer in Qassim. However for mid-summer a group of cvs with different heat tolerance strategies are needed for such a program.

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الإزهار والإثمار في الطماطم بمنطقة القصيم، المملكة العربية السعودية أثناء فصل الصيف

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ملخص البحث. أجريت هذه الدراسة للتعرف على العوامل الفسيولوجية التي تؤدي إلى انخفاض إنتاجية الطماطم الحقلية بمنطقة القصيم، المملكة العربية السعودية أثناء فصل الصيف. تمت زراعة صنف الطماطم «بيرسون أ ١ ـ المحسن» في يناير، فبراير ومارس خلال عامي ١٩٨٧، ١٩٨٨م. انخفض الوزن الكلي للثمار المنتجة انخفاضًا ملموسًا عند الزراعة في فبراير، وانخفاضًا شديدًا عند الزراعة في مارس، بالمقارنة مع الزراعة في يناير. يعزى هذا إلى الانخفاض في متوسط وزن الثمرة، والذي يرجع بدوره إلى الانخفاض في عدد البذور داخل الثمرة ونسبة الثمار العاقدة عند الزراعة في فبراير، وإلى هذين العاملين بالإضافة إلى انخفاض عدد الأزهار عند الزراعة في مارس. يعزى عدم عقد الثمار وتكون البذور إلى فشل عملية الإخصاب نتيجة عدم تفتح المتك تفتحًا طبيعيًا واستطالة المياسم بحيث أصبحت مرتفعة عن مستوى المتك عند الزراعة في فبراير أو نتيجة عدم تفتح المتك تفتحًا طبيعيًا، انخفاض حيوية وإنتاج حبوب اللقاح، استطالة المياسم وانخفاض حيوية البويضات وربما موت الأجنة عند الزراعة في مارس.

من المحتمل أن يكون لدرجة الحرارة المرتفعة الأثر الفعال في إحداث هذه النتائج، وبالتالي فإنه يوصى بإدخال الأصناف المقاومة للحرارة المرتفعة في برامج التربية لاستنباط بعض الأصناف التي تناسب الزراعة الصيفية بمنطقة القصيم.