A

सुसंस्कृत शिक्षणाला मायेची जोड
देणारी माझी आई, **सौ. आक्का**
व मी भरपूर शिकावं यासाठी
सतत परिश्रम करणारे माझे
वडील, **श्री. आण्णा**
यांच्या चरणी
अर्पण...

...गजानन

STUDIES ON RADIAL FRUIT CRACKING IN TOMATO
(*Lycopersicon esculentum* Mill.)

By

GAJANAN DHONDIRAM PATIL

B.Sc. (Agri.) First class with Distn.
(Reg.No.95143)

A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA

in partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

HORTICULTURE

DEPARTMENT OF HORTICULTURE

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH,
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APPROVED BY

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DEPARTMENT OF HORTICULTURE

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI
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1998

CANDIDATE'S DECLARATION

I here by declare that this thesis or part

thereof has not been submitted by me

or any other person to any other

University or Institute

for Degree or

Diploma

Place : MPKV,Rahuri.

Dated : 2 / 3 /1998 (G.D. Patil)

Dr. R.S. Patil
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Maharashtra State (INDIA)

CERTIFICATE

This is to certify that the thesis entitled, "STUDIES ON RADIAL FRUIT CRACKING IN TOMATO (*Lycopersicon esculentum* Mill.)", submitted to the Mahatma Phule Krishi Vidyapeeth, Rahuri, for the award of the degree of MASTER OF SCIENCE (AGRICULTURE) in HORTICULTURE, embodies the results of a *bona fide* research carried out by SHRI. GAJANAN DHONDIRAM PATIL, under my guidance and supervision and that no part of the thesis has been submitted for any other Degree, Diploma or publication in any other form.

The assistance and help received during the course of this investigation have been duly acknowledged.

(R.S. Patil)

Place : Rahuri
Dated : 2/3 /1998.

Dr. V.M. Pawar,
Associate Dean,
Post Graduate Institute,
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Maharashtra State (INDIA).

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Place : Rahuri (V.M. Pawar)

Dated : 23/ 3 /1998.

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Patil

Place : Rahuri (G. D. Patil)

Date : 2/3 /1998.

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ABBREVIATIONS AND SYMBOLS

B	:	Bhagyashree
C.D.	:	Critical difference
cm	:	Centimeter (s)
cv.	:	Cultivar
D	:	Dhanashree
et al.	:	And others (et alii)
etc.	:	Et cetera
Fig.	:	Figure
g	:	Gramme (s)
ha	:	Hectare (s)
kg	:	Kilogram (s)
m	:	Metre (s)
No.	:	Number
N.S.	:	Non significant
q	:	Quintals
S.E.m ±	:	Standard error mean
Var.	:	Variety
%	:	Per cent
@	:	At the rate of

ABSTRACT

STUDIES ON RADIAL FRUIT CRACKING IN TOMATO
(*Lycopersicon esculentum* Mill.)

By

GAJANAN DHONDIRAM PATIL

A Candidate for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

1998

Research Guide	:	Dr. R.S. Patil
Department	:	Horticulture

The present investigation entitled "Studies on radial fruit cracking in tomato (*Lycopersicon esculentum* Mill.)" was carried out for varietal improvement of cv. Dhanashree and cv. Bhagyashree especially for fruit cracking resistance. The problem of radial fruit cracking was investigated genetically as well as agronomically.

In genetical studies, thirteen selections of cv. Dhanashree and eight selections of cv. Bhagyashree, already developed by the "Tomato Improvement Project", M.P.K.V., Rahuri were screened for fruit cracking resistance along with susceptible and resistant checks. While screening, most of the selection progenies recorded significantly lower fruit cracking (27-42 %) than the original cultivar (58-59 %), as a susceptible check, however it was significantly more than the resistant check (20-22 %) i.e. two F_1 hybrids, Rajashree and S-28. Promising selections were identified as D_{11} from cv.

Dhanashree and B_7 and B_6 from cv. Bhagyashree which recorded minimum fruit cracking (i.e. 32, 27 and 27 %, respectively).

Furthermore twenty-three individual plants were selected from the plant population of twenty-one selection progenies and selection mean was compared with the population mean. A significant selection improvement was noticed over population as the least fruit cracking (0-16 %) was noticed in individual selected plants as compared to population mean of selection progenies (27-55 %) and also the resistant check cultivars (20-22 %). Three individual plants (one from cv. Dhanashree i.e. D-6-2 and two from cv. Bhagyashree i.e. B-3-1 and B-7-1) were identified as complete crack-free genotypes.

While studing genetical parameters, it was observed that the maximum genetic variability was found for the character, fruit cracking (GCV 26-31 %) which was followed by pericarp thickness (GCV 13-17 %), equatorial diameter and polar diameter (GCV 6-10 % and 4-6 %, respectively). But due to high estimates in heritability (96-98 %) and expected genetic advance (21-22), only character radial fruit cracking was observed under additive gene action and can be improved by the simple selection method.

In agronomical studies, the boron application was found effective in controlling radial fruit cracking in susceptible tomato cultivar. The treatment of combined borax application of soil application (i.e. 15 kg/ha) and foliar spray (0.25 % borax) was found the most effective and recorded the least fruit cracking (16 %) followed by the sole treatment of boron foliar spray (19 %) and soil application (20 %) as compared to 45 % fruit cracking in the control treatment. Boron application not only effectively controlled the radial fruit cracking but also improved the quantitative traits (such as yield, fruit set, fruit size and fruit weight) and qualitative traits (i.e. pericarp thickness and TSS content).

Pages 1 to 52

INTRODUCTION

1. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.), a solanaceous fruit vegetable, has prime position among vegetable crops and in sub-tropical region, its cultivation is possible almost all the year round. It is the most popular vegetable all over the world due to its versality in fresh and processed form. Tomato is mainly used in salad because tomatoes are good source of vitamins A, B and C, and mineral elements such as calcium, phosphorus, magnesium, sodium, boron and zinc. Tomato fruits also provide fibres and add crispyness as well as taste in the salad. Furthermore, tomato is an unique source for pigments (e.g. lycopene and β-carotene), organic acids (citric, malic, amino and glutamic acids), T.S.S. and titrable acidity. Particularly on these traits, the processing quality of tomato product is dependent. Tomato is, therefore, processed into variety of products like soup, juice, ketchup, puree, paste, salad, sauce, pickles etc.

Today, tomato outranks all other vegetables, except potato, in popularity and also in value. However, it ranks first as a processed vegetable. In India, tomato has been popular since last five decades. The fruit is cultivated throughout the country. In India it is grown on 321 thousand hectares with a total production of 5029 thousand metric tonnes. The average yield per hectare of India is 15.67 tonnes, while the world average yield is 27.18 tonnes per hectare (Anonymous, 1994). In Maharashtra, the area under this crop has increased from 14,000 hectares in 1978 to 25,987 hectares in 1992 (Singhal Vikas , 1995). In Maharashtra, tomato cultivation is concentrated in Nasik, Pune and Ahmednagar districts, mainly for long distance marketing. Therefore, the cultivation of F_1 hybrids is getting popular because of its excellent keeping qulaity. The average yield per hectare is 40-50 tonnes per hectare. However, certain disadvantages came forward with the cultivation of F_1 hybrids, such as very high seed cost, susceptibility to viral diseases, high cost for plant protection etc. The cost of cultivation for a F_1 hybrid is ranging between Rs. 25,000 to Rs. 35,000 per acre. More importantly, the qualitative traits (such as fruit juice, organic acid, flavour and taste) are adversely affected in hybrid tomato fruit. The shelf-life of such fruits is improved mainly due to increasing core size, limiting the locular size at periphery and thickening of pericarp.

To achieve an optimal balance between the poor keeping traditional open-pollinated tomato varieties and firm-fruited F_1 hybrids, the Mahatma Phule Krishi Vidyapeeth, Rahuri has developed two tomato cultivars viz., "Dhanashree" and "Bhagyashree" in 1992. The cultivar Dhanashree is high yielding variety (80-100 t/ha) with organge-red fruits (60 g) with 7-8 days shelf-life and therefore suitable for fresh markets. While, cv. Bhagyashree is developed for processing as fruits are deep red in colour, lower seed content and higher TSS. The yield of cv. Bhagyashree is 60-80 t/ha. The unique characteristics of these two cultivars are genetical built-up field tolerance against viral diseases, rich in qualitative traits and low cultivation cost. Hence, these two cultivars are popular among the small farmers.

However, since 1993 the radial fruit cracking was observed in *kharif* season. It is mostly due to irregular rainfall in early months of monsoon season. If severe dry climatic conditions at fruiting stage is followed by heavy rains, it results into considerable fruit cracking in these two cultivars. To overcome this problem, the systematic research work was initiated at Tomato Improvement Scheme, M.P.K.V., Rahuri and promising selections were made for cracking resistance.

The tomato cultivation has many problems (i.e. biotic and abiotic). Fruit cracking is one of the most damaging problem. It has been a serious consequence to the tomato grower, marketer and processor. Cracking decreases marketable yields of tomatoes and often makes them unprofitable. There are four types of cracking observed in tomato : radial, concentric, cuticular and burst. Of these, radial cracking is more damaging (Kalloo, 1985). Radial cracking mostly occurs at ripe stage whereas concentric cracking is more at mature-green stage (Koske et al., 1980). In general, cracking causes losses upto 8-10 per cent and under congineal conditions it goes upto 40-50 per cent. There are various factors associated with incidence of fruit cracking. The important among them are fruit water potential (Murase, 1981), soil moisture (Kamimura et al., 1972), cell turgidity (Singh and Young, 1970), foliage and sugar content (Nueuchi and Handa, 1961) and also under genetical control (Armstrong and Thompson, 1967). Fruit cracking in tomato can also be controlled by application of boron (Kalloo, 1985).

In present study the promising isogenic selections of cvs. Dhanashree and Bhagyashree have been assessed for cracking resistance in *kharif* season. Similarly, the effect of boron on fruit cracking is also studied.

The main objectives of the present study are :

1. To screen the promising selections of cv. Dhanashree and cv. Bhagyashree for cracking resistance.
2. To advance the generation of selection progeny by selecting an individual plants for fruit cracking resistance and compare the selection mean with the population mean.
3. To estimate the genetical parameters like genetic coefficient of variation, heritability and genetic advance for fruit cracking.
4. To study the effect of boron on fruit cracking.

Thus, in present study the problem of fruit cracking is tackled by both ways i.e. by genetically as well as chemically.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Tomato (*Lycopersicon esculentum* Mill.), is one of the most important vegetable crops grown in all the seasons on large scale. Most of the research work carried out pertains to the effect of agronomic or cultural practices. Although the majority of work is carried on causes and circumstances of tomato fruit cracking, very meagre research has been carried with regard to genetical improvement and chemical control of fruit cracking in tomato. Review of the relevant literature in respect of cracking is briefly summarised in this chapter.

2.1 Factors and circumstances for occurance of fruit cracking

Koske et al. (1980) reported that there are four types of cracking : radial, concentric, burst and cuticular. Of these, radial fruit cracking is more damaging. Radial fruit cracking is mostly at the ripe stage while concentric fruit cracking is more at mature green stage.

According to Murase (1981) cracking is common during the rainy season when the rains follow a long dry spell. The presence of water on the surface of the fruit is more conducive to cracking than the high soil moisture. Fruit water potential increase of two bars has been found to be associated with fruit cracking. Kamimura et al. (1972) stated that there is effect of soil moisture, rain and dew and plant vigour on the occurance of minute cuts and cracks.

However, Drews (1978) has found that cracking in tomato is not associated with fertilizer application, soil moisture or type of irrigation, but with the high day temperature (> 30^0C) followed by low night temperatures (< 10^0C) with high relative humidity (> 80 %). Singh and Young (1970) has concluded that reduced transpiration has increased cell turgidity and contributed to tomato fruit cracking.

Bakker (1988) reported that cracks occured on fruits 6-7 weeks after the fruit set in last phase of fruit growth. The extent of cracking increased with the increase in the period from occurance to harvest. Cracking was most marked at higher Relative Growth Rate (RGR) and long periods from fruit set to harvest. The percentage of cracked fruits varied from 10-80 per cent over the total production period. Similarly, Outer and Veendall (1987) concluded that the cracks arise 2-3 weeks before the fruit harvest, when the growth of epidermis cells was at its maximum. It was further concluded that the cracking was caused largely by the fluctuation in relative humidity and high cellular tension in fruits as a result of excessive water uptake.

Ohta et al. (1991) reported that the percentage of cracked fruits and crack length were decreased by low humidity and increased by high humidity. The highest penetration resistance of both skin and flesh and tensile strength of skin were found in fruits grown under low humidity, indicating that the fruit texture was firmer under the low humidity.

According to Frazier (1934), an absorption of external moisture by corky spots or the corky layer of the stem-end, age of fruit, position of the fruit in cluster, chemical composition and size of the fruit are associated with the occurance of fruit cracking. While, Peet and Willits (1995) noticed increased cracking with providing excess irrigation water.

Brown et al. (1934) reported that the severity of cracking was reduced by the shading of plants while it was increased by excess irrigation at advance stage of ripening.

Ehret et al. (1993) reported that under the glasshouse conditions, fruit-prunning in tomato substantially increased the plant leaf/fruit ratio and significantly increased the incidence of cracking.

Young (1959) stated that resistance to cracking is associated with the pink fruit colour, high number of fruits per plant, low average number of locules per fruit, small fruit size and determinate plant growth habit.

Frazier (1935) concluded that the cracking of tomato fruits on plants prunned to a single stem was more severe than fruits from non-prunned. The N, P and K application to soil in large amounts, had no appreciable effect on cracking of tomato fruits. According to Borkowski and Srzednicka (1989), the fruits cracked less on the plants with ample foliage and where the leaves were not removed.

According to Buitelaar and Eelhart (1986), wider planting resulted in more skin cracking and shorter shelf life. Similarly, Bleyaert (1990) reported that the fruit cracking was reduced with plastic mulches which maintained a constant level of soil moisture.

2.2 Fruit characters and cracking

Uhlinger (1963) reported that fruit softness was positively correlated with cracking. The K content of the pericarp and of the septa from the stem ends of the red ripe fruits were positively correlated with radial crack indices.

According to Janse (1985), this physiological disorder was associated with low skin elasticity and sudden fruit swelling and the incidence of fruit cracking in tomato was lower with the use of moisture repellent screens.

Cotner et al. (1969) reported that the fruits showing resistance to cracking had flattened epidermal cells. These fruits had a more extensive vascular system. The distribution of water absorbed by the fruit may be a factor in crack resistance.

Nueuchi and Handa (1961) reported that low incidence of radial cracking is associated with high elasticity of fruit skin and low sugar content.

Golias and Nemcova (1986) assessed nine cultivars for their resistance to cracking and reported that the variety's resistance to cracking is determined by the properties of its skin and surface layers and by its degree of water absorption which is determined by degree of permeability of skin. Cracking resistance is related to low degree of water absorption and elastic skins.

While studing cracking in apple, Faust and Shear (1972) reported that the thickness of the cuticle is correlated to cracking. The cultivars with thin cuticle, or areas of fruit having thin cuticle are more subject to cracking. The structure of skin is important. The cuticle cracks if it is unable to expand with the internal pressure created by the dividing and growing epidermal cells. Apple (*Malus pumila*) in humid environment develop a thin or almost no cuticle. Also, water may diffuse into the epidermal cells through the cuticular cracks creating higher turgor pressure within, which may lead to rupture of cells. Apples exposed to the sun have inflexible cells which are unable to expand in response to increasing turgor pressure and thus burst easily.

2.3 Genetical Improvement for fruit cracking

Young (1963) reported that cracking resistance is polygenic and partly quantitative and can be minimised by planting resistant varieties. Resistance to radial, concentric, burst and cuticular cracking appears to have different inheritance patterns (Young, 1962). Radial cracking is determined by two independent pairs of recessive genes, crcr and rlrl (Young, 1959). The data support that concentric cracking and bursting are genetically controlled. These genes are located on the same chromosome as the gene for growth habit (*SP*) and ripe fruit (*V*).

Uhlinger (1963) suggested that under conditions of mild stress, resistance to radial cracking is inherited as a dominant character, but under conditions of more severe stress it is inherited as a recessive character.

Hepler (1961) reported that gene action for radial and concentric cracking is additive and partially dominant for succeptibility. Heritability values are higher for radial than concentric cracking.

Armstrong and Thompson (1967) reported that resistance to fruit cracking is controlled by several genes. There is also a pleiotropic effect of fleshy calyx gene (*Fl*) which is resistant to cracking (Chu and Thompson, 1971).

Prashar and Lambeth (1960) stated that the cracking in tomato is quantitative character and the inheritance may involve several major and minor genes with unidentical effects. The best is, it was assumed that there are two strong and two weak genes for cracking with interallelic interaction. The resistance is not controlled by same genes in all varieties and cracking is also observed under incomplete dominant gene action.

While exploiting male sterile lines in F_1 hybrid programme in tomato, Singh and Nandapuri (1970) observed that the male sterile lines transmitted a high degree of fruit cracking to the progeny.

Cortes et al. (1983) studied 62 genotypes to establish correlations between the radial and concentric cracking and concluded that the susceptibility to form large and small cracks was controlled by same genetic system (r_G = 0.85 - 0.95), yet there was genetic difference between susceptibility to radial and concentric cracking (r_G = 0.53 - 0.68).

Gilbert et al. (1961) have produced hybrids by crossing multiple disease resistant, unrelated tomato lines from Florida and Hawaii have showed resistance to cracking along with resistance to other diseases. Gill and Nandapuri (1970) compared varieties for resistance to fruit cracking in tomato and listed varieties Red Belt 1, Best of all, S.12, No.15, and 39 R in the decreasing order of susceptibility. Janse (1985) found Turbo and Marathon cultivars as least susceptible to cracking. Gardner (1992) reported that NC8276, the inbred parent line of "Mountain spring" , a F_1 hybrid, has excellent resistance to radial, concentric and cuticle cracking. "Mountain Spring" shows same resistance as its parent line.

Abbot et al. (1985) compared crack susceptible (Machigan - ohio hybrid) and crack resistant (Montfavet F_1 hybrid) and reported that genotype had greatest effect on fruit cracking, with 3.8 per cent by weight cracked fruits in the crack resistant compared with 35.3 per cent in crack susceptible cultivar.

2.4 Effect of boron on fruit cracking

Dinger (1962) observed cracking of skin in tomatoes being associated with boron deficiency and suggested boron sprays of 0.3 - 0.4 per cent.

Maynard *et al.* (1959) reported that cracking in tomato occurs as a result of the rupture of thin-walled collenchyma cells if boron deficiency occurs when the fruit is approaching maturity.

Yamauchi *et al.* (1986) stated that boron deficiency induced a decrease in the amount of calcium association with pectin constituents and inhibited the calcium translocation to upper leaves thus induces abnormal changes in the calcium metabolism in the cell wall.

Pilbeam and Kirkby (1983) stated that boron is essential to maintain the structural integrity of the plant membranes and its deficiency causes changes in membrane permeability.

Katherine (1926) observed that boron deficiency in *Vicia faba* causes hypertrophy of the cambium cells followed by its disintegration with discolouration.

Kalloo (1985) recommended soil application of borax at the rate of 10-15 kg/ha or its spray at 0.25 per cent at the fruiting stage reduces the fruit cracking in the tomato crop.

2.5 Effect of boron on yield contributory characters

Magalhaes *et al.* (1981) reported that soil application of boron at 20 to 40 kg/ha increased the total yield and first grade yield and decreased physiological disorders in tomato.

Pails and Hodossi (1976) reported that in tomato, foliar fertilizer application along with micronutrients (N,P,K + Mg, B, Mo) increased total yield, advanced ripening and reduced the fruit cracking.

Mei *et al.* (1984) observed in tomatoes that fruit number, yield per plant and individual fruit weight is increased by spraying boron. Also, Castellane *et al.* (1982) reported that best yields were obtained by soil application of borax at 15 kg/ha applied 14 days after sowing. Similarly, Dzhavakhishvili and Egorashvili (1985) reported that soil application of boron (4 kg/ha) increased yields in tomato by 11 per cent. Foliar application was less effective than soil application. However, combining soil and foliar application has greatest effect in increasing yields by 13-15 per cent. It also increased total sugars.

According to Agwah and Mahmoud (1994), three foliar sprays of 0.25 per cent borax applied at weekly interval increased fruit set in tomato. These foliar sprays also increased leaf dry matter, early and total yields. Pandita *et al.* (1979) reported that maximum fruit set was obtained on plants sprayed with 1 ppm boron. This spray also gave highest total yield per plant (3.01 kg).

Das and Das (1981) reported that combination of boron and urea application gave increased plant height, number of shoots per plant, number of leaves per plant, leaf area, number of fruits per plant and yields in tomato.

Arora *et al.* (1982) reported that foliar spray of boron (as H_3BO_3) at 1 ppm on tomato decreased the number of locules per fruit and increased the TSS.

2.6 Effect of boron for control of fruit cracking in other horticultural crops

Wundermann (1981) studied the cracking (russeting) in apples (*Malus pumila*) and recommended spray of 0.3 per cent borax to reduce cracking. The incidence of fruit cracking was also reduced by the spray of borium at 0.13 per cent, sprayed two times at ten-day interval on Golden Delicious cultivar of apple (Wertheim, 1980).

Shorrocks and Nicholson (1979) reported that spray application of boron generally reduces the incidence of cracking in apples.

Chandel and Ganesh (1995) reported that highest yield and lowest incidence of cracking (6.7 %) in litchi was observed with NAA spray at 20 ppm and borax at 0.4 per cent. Singh *et al.* (1990) reported that spraying boric acid (0.005 %) was effective in reducing fruit cracking and increasing yields in pomogranate (*Punica granatum*).

Ghanta and Mitra (1993) reported the early flowering in banana (*Musa paradisica*) with the spray of 0.2 per cent boric acid along with copper sulphate.

MATERIALS AND METHODS

3. MATERIAL AND METHODS

The present investigation entitled "Studies on radial fruit cracking in tomato (*Lycopersicon esculentum* Mill.)" was carried out at the Tomato Improvement Project, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri during *kharif* season of 1996.

3.1 Experimental site

The experimental material was grown in *kharif* (June-Nov.) of 1996 at Vegetable Research Farm, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar.

Geographically, central campus of M.P.K.V., Rahuri is situated between 19°47' to 19°57' North latitude and 74°19' to 74°32' East longitude with elevation of 525 metre above mean sea level. The soil of the experimental plot was medium black and well drained with uniform well levelled topography.

Climatically, this area falls in semi-arid, sub-tropical zone with the annual rainfall varying from 307 mm to 619 mm. The average annual rainfall being 475 mm. Most of the rainfall is received through south-west monsoon. The annual mean maximum and minimum temperatures are 34.5°C and 18.3°C respectively.

3.2 Design and layout of the experiment

The following two different experiments were conducted as a genetical and agronomical studies.

1. Genetical improvement against radial cracking
2. Effect of boron on fruit cracking of tomato.

3.2.1 Genetical improvement against radial fruit cracking

The thirteen isogenic selections of cv. Dhanashree and eight isogenic selections of cv. Bhagyashree were screened for cracking resistance in Randomised Block Design (R.B.D.) along with susceptible check (i.e. original cultivar) and resistant checks (i.e. two commercial F_1 hybrids).

3.2.1.1 Screening of isogenic selections of cv. Dhanashree for cracking resistance

a. Replications : 2

b. Treatments : 16

1. D-1	2. D-2	3. D-3	4. D-4
5. D-5	6. D-6	7. D-7	8. D-8
9. D-9	10. D-10	11. D-11	12. D-12
13. D-13			

Susceptible check

14. cv. Dhanashree

Resistant check

15. Rajashree (F_1)
16. S-28 (F_1)

c. Plot Size : 1.80 x 3.60 m.

d. Planting distance : 60 x 30 cm

e. Number of plants/plot : 30

N

D_1	D_2	D_3	D_4
D_5	D_6	D_7	D_8
D_9	D_{10}	D_{11}	D_{12}
D_{13}	D-Check	Rajashree	S-28

RI

D_{11}	D_9	D_{12}	D_{10}
D_3	D_1	D_4	D_2
Rajashree	D_{13}	S-28	D-Check
D_7	D_5	D_8	D_6

RII

Design : Randomised Block Design

Replications : Two

Treatments : 16

Plot size : 1.80 x 3.60 m.

Fig. 1a. Plan of Layout : For the selections of cv. Dhanashree

B_1	B_2	B_3	B_4	
B_5	B_6	B_7	B_8	RI
B-Check	Rajashree	S-28		

B_6	B_7	B-Check	B_2	
B_3	Rajashree	B_8	S-28	RII
B_1	B_4	B_5		

B_8	B_5	B_3	Rajashree	
B_4	S-28	B_2	B_1	RIII
B_6	B_7	B-Check		

Design	:	Randomised Block Design
Replications	:	Three
Treatments	:	11
Plot size	:	1.80 x 3.60 m

Fig. 1b. Plan of Layout : For the selections of cv. Bhagyashree

T_1	T_2	T_3	T_4	RI
T_4	T_3	T_2	T_1	RII
T_3	T_1	T_4	T_2	RIII
T_2	T_4	T_1	T_3	RIV
T_1	T_2	T_3	T_4	RV

Design	:	Randomised Block Design
Replications	:	Five
Treatments	:	Four
Plot size	:	1.80 x 3.60 m

Fig. 1c. Plan of Layout : Boron application

3.3 Cultural practices

Land preparation, manuring, irrigation, plant protection, weeding etc., were carried out as per the package of practices recommended by the Department of Horticulture, M.P.K.V., Rahuri.

3.4 Experimental material

In the cultivars Dhanashree and Bhagyashree, the selections were made for cracking resistance by the Tomato Improvement Project, M.P.K.V., Rahuri. The seeds of these promising selections, F_1 hybrids (Rajashree and S-28) and original cultivars Dhanashree and Bhagyashree were procured from the Tomato Improvement Project, M.P.K.V., Rahuri.

3.5 Screening of genotypes

The thirteen selections from cv. Dhanashree and eight selections from cv. Bhagyashree developed by the Tomato Improvement Project, M.P.K.V., Rahuri for radial fruit cracking resistance were further screened in present studies. The cvs. Dhanashree and Bhagyashree which were more susceptible to fruit cracking were considered as a susceptible control. Where as, two F_1 hybrids (i.e. Rajashree and S-28) which were found to be the least susceptible to fruit cracking were considered as resistant controls.

The incidence of fruit cracking was continuously observed from the fruit set upto the harvest of the crop. The individual plants which showed cracking resistance at initial stages were selected and labelled. The fruits of these selected plants were harvested separately and seeds were used to advance further generation. The observations regarding number of cracked fruits were recorded at each picking and the percentage of fruit cracking was worked out on the basis of total number of cracked fruits in entire harvest period. Similarly, the selected plants were also evaluated for fruit cracking and their performance was further compared with the population mean.

3.6 Application of boron

Boron in the form of borax was applied in four treatments. The first treatment was soil application of borax which was given at the time of second irrigation to individual plant by ring method at the rate of 15 kg/ha. The second treatment was combination of the two treatments i.e. soil application combined with foliar spray of borax. The third treatment was foliar spray of 0.25 per cent borax which was given when fruits were at mature - green stage. The fourth treatment was control i.e. without boron application.

3.7 Observations to be recorded

3.7.1 Main observations

3.7.1.1 Per cent fruit cracking

It is calculated as the ratio of number of cracked fruits from the entire harvest to the total number of fruits to be harvested and multiplied by hundred.

3.7.1.2 Fruit yield

The total number of fruits (irrespective of cracking) from all the picking were recorded per plot and yield was calculated per tree (by using plant population) and for per hectare (by using hectare factor).

3.7.2 Ancillary observations

The five representative plants were selected randomly and used for recording ancillary data.

3.7.2.1 Height of plant (cm)

Height of plant was recorded at the time of final harvest. The measurements were taken from ground level to the tip of main branch.

3.7.2.2 Number of primary branches per plant

The mean number of primary branches were recorded from selected five plants.

3.7.2.3 Days to 50 per cent flowering

The average days required for flowering of 50 per cent plant population were calculated from date of sowing of nursery.

3.7.2.4 Number of flowers per cluster

The number of flowers in each cluster were counted at the full bloom stage and the mean worked out from selected five plants. These clusters were also tagged to note down observations for fruit set.

3.7.2.5 Number of fruits per cluster

The number of fruits per tagged cluster were counted to work out average number of fruits per cluster.

3.7.2.6 Per cent fruit set

The per cent fruit set was calculated as the average number of fruits per cluster divided by number of flowers per cluster multiplied by hundred.

3.7.2.7 Average polar diameter of the fruit (cm)

Average polar diameter of the five randomly selected fruits was measured with the help of vernier calliper.

3.7.2.8 Equatorial diameter of the fruit (cm)

Average equatorial diameter of the five randomly selected fruits was measured with the help of vernier calliper.

3.7.2.9 Fruit shape index

It is calculated as the ratio of equatorial diameter to polar diameter of the fruit.

3.7.2.10 Fruit weight (g)

The average fruit weight was calculated by the ratio of total fruit weight of the harvest and the total number of fruits of harvest.

3.7.2.11 Per cent total soluble solids

Randomly ten fruits from each selected plants were evaluated for TSS. The individual fruit juice was examined by the hand refractometer and the average TSS was worked out.

3.7.2.12 Pericarp thickness (cm)

The pericarp thickness of cutted fruit surface was examined by the vernier calliper and the average worked out.

3.7.2.13 Number of locules per fruit

The above cut-open fruits were observed for number of locules in each fruit separately and then the average is calculated.

3.8 Statistical analysis

The observations were recorded for fruit and plant characteristics. While analysing the data statistically, the percentage values of characters were worked out. The genetic constants such as genetic coefficient of variation and heritability percentages were calculated by adopting the standard statistical procedure suggested by Burton and De Vane (1953). Genetic advance was worked out as per the method given by Lush (1949).

3.8.1 Genotypic coefficient of variation

$$GCV = \frac{\sqrt{\text{Genotypic variance}}}{\overline{X}} \times 100$$

Where,

$\overline{X}$ = is the mean of the character.

3.8.2 Heritability percentage (Broad sense)

$$H = \frac{G}{G + E} \times 100$$

Where,

G = Genotypic variance was obtained as below.

$$G = \frac{\text{Treatment M.S. - Error M.S.}}{\text{Number of replications}}$$

E = Error variance

3.8.3 Expected genetic advance (EGA)

Expected genetic advance at 5 per cent selection intensity calculated by the following formula.

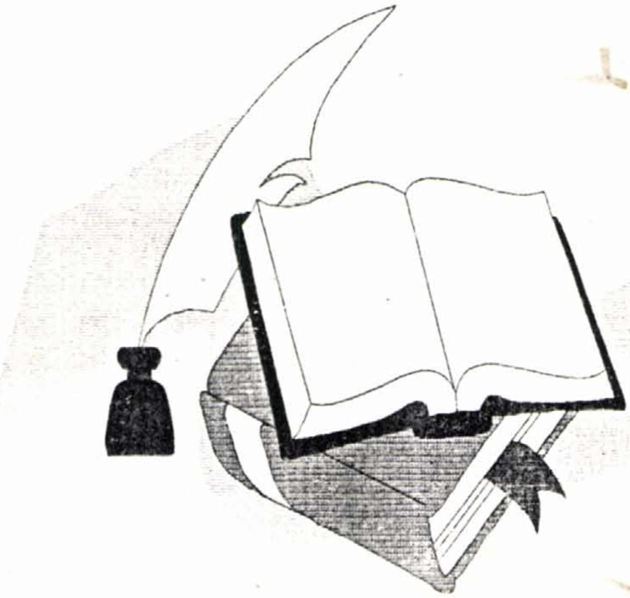
$$EGA = \frac{V_G}{\sqrt{V_P}} \times K$$

Where,

V_G = Genotypic variance

V_P = Phenotypic variance

K = 2.06



RESULTS

4. EXPERIMENTAL RESULTS

The present investigation entitled "Studies on radial fruit cracking in tomato (*Lycopersicon esculentum* Mill.) was carried out during the *kharif* season of 1996 at Vegetable Research Farm, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri. The experiment was two-fold : Firstly, to carry out the screening of promising selections of cvs. Dhanashree and Bhagyashree for cracking resistance as a genetical improvement and secondly, to evaluate the effect of boron application on fruit cracking in tomato, as a chemical control.

The observations were recorded on fruit cracking, pericarp thickness and on other biometric plant characters. The results obtained for the selections of cvs. Dhanashree and Bhagyashree were recorded under separate sub-headings. The results regarding the effect of boron on fruit cracking is also presented.

4.1 Screening of promising selections of cv. Dhanashree for radial fruit cracking

The data regarding the radial fruit cracking and other biometric characters of thirteen selected isogenic lines of cv. Dhanashree and of other check cultivars is presented in Table 1.

4.1.1 Radial fruit cracking

The data presented in Table 1 reveal that the significant variation in fruit cracking was noticed in the genotypes under study. Among the selections of cv. Dhanashree the significantly lowest fruit cracking was observed in selection D11 (32.17 %) followed by D13 (37.37 %), D3 (37.93 %), D6 (37.96 %), D1 (38.02 %) and D8 (38.28 %) which where at par with each other.

Table 1. Comparative performance of promising selections of cv. Dhanashree for fruit cracking and other plant characters.

Selections	Fruit cracking (%)	Yield (q/ha)	Yield/ plant (g)	Fruit weight (g)	Equit'al diameter (cm)	Polar diameter (cm)	*Shape index	Pericarp thickness (cm)	TSS (%)	Height of plant (cm)	No.of branc-ches	Flowers per cluster	Fruits per cluster	Fruit set (%)	Days to 50 % flowering	No.of locules
D_1	38.02	388.09	1289.0	55.1	4.45	4.67	0.95	0.83	3.27	69.10	4.3	10.5	5.4	42.87	84.7	2.9
D_2	51.70	349.85	1091.0	57.9	4.93	4.96	0.99	0.63	3.31	69.00	3.9	10.3	3.2	31.07	84.7	3.0
D_3	37.93	421.57	1336.0	54.4	4.33	4.61	0.94	0.84	4.03	69.00	4.1	10.6	4.9	46.22	84.5	2.8
D_4	55.82	358.06	1190.0	58.1	4.90	5.05	0.97	0.61	3.98	68.90	4.0	9.9	3.1	31.30	84.6	3.0
D_5	48.72	361.85	1071.0	57.0	4.77	4.79	0.99	0.72	2.97	69.30	3.9	10.0	3.6	30.47	84.9	2.9
D_6	37.96	339.52	1196.0	55.3	4.36	4.62	0.94	0.83	3.49	69.75	4.0	10.7	4.8	44.86	84.2	2.8
D_7	48.38	357.90	1051.0	56.9	4.65	4.76	0.98	0.71	3.11	70.60	4.7	10.4	3.8	36.55	84.7	3.0
D_8	38.28	368.00	1177.0	55.9	4.54	4.71	0.96	0.78	4.09	69.00	3.6	10.4	4.3	41.37	84.7	2.9
D_9	52.34	375.70	1221.0	58.7	4.86	5.07	0.96	0.61	4.15	69.90	4.3	10.0	3.1	30.95	84.6	3.0
D_{10}	49.99	356.25	1147.0	57.5	4.89	4.87	1.00	0.63	3.43	70.00	4.5	9.9	3.2	32.30	84.5	3.0
D_{11}	32.17	360.74	1126.0	52.8	4.15	4.47	0.93	0.86	3.83	69.70	4.0	10.5	5.0	47.62	84.4	2.7
D_{12}	38.64	339.25	1198.0	56.3	4.54	4.66	0.97	0.76	3.05	69.30	4.0	10.3	4.1	39.79	85.0	2.9
D_{13}	37.37	348.79	1069.0	53.1	4.29	4.51	0.95	0.85	4.04	69.60	3.8	10.4	4.9	47.11	84.5	2.7
D-Check	58.00	347.86	1202.0	58.5	4.96	5.09	0.97	0.61	4.09	69.70	4.2	9.9	3.1	32.82	84.6	3.0
Rajashree	20.55	415.83	1357.0	52.0	4.13	5.13	0.81	0.81	3.02	70.40	5.3	10.7	4.9	45.80	84.1	2.8
S-28	22.13	416.94	1336.5	52.2	4.16	4.62	0.90	0.81	3.81	69.95	5.3	10.6	4.8	45.28	84.3	2.9
General mean	41.75	369.14	1191.0	55.7	4.56	4.79	0.95	0.74	3.67	69.57	4.2	10.3	4.1	39.15	84.6	2.9
S.Em.±	1.377	16.616	23.324	0.389	0.040	0.018	-	0.011	0.015	1.145	0.117	0.131	0.098	1.491	0.589	0.083
CD at 5%	4.149	50.064	70.282	1.172	0.121	0.054	-	0.034	0.045	N.S.	0.352	0.396	0.296	4.492	N.S.	N.S.

* Shape index = Equatorial diameter/Polar diameter

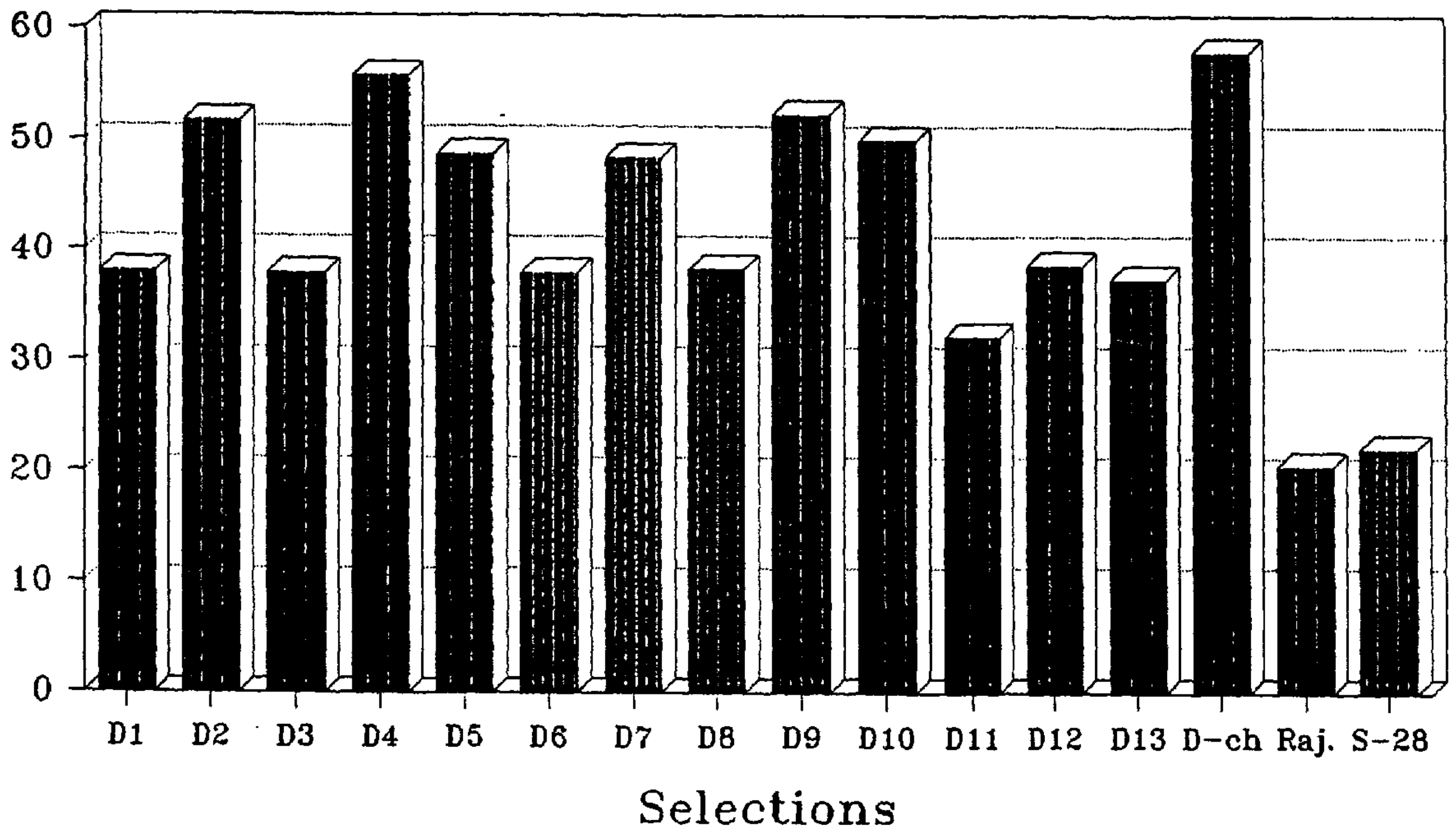


Fig.2. Comparative performance of promising selections of cv.Dhanashree for fruit cracking

However, although the significantly lower fruit cracking was observed in certain selections of cv. Dhanashree compared to susceptible check (58.00 %), the fruit cracking in these promising selections are significantly higher than resistant F_1 hybrid checks i.e. Rajashree (20.55 %) and S-28 (22.14 %). While, the highest cracking was recorded in the genotype D_4 (55.82 %) and D9 (52.34 %) which was comparable with the susceptible check (58.00 %). The fruit cracking in D11 was significantly lower than other genotypes showing its superiority among the selections of cv. Dhanashree.

4.1.2 Pericarp thickness (cm)

The data regarding the mean pericarp thickness of the fruit in different genotypes of cv. Dhanashree is presented in Table 1. It was evident from the data that the mean pericarp thickness of the genotype D11 (0.86 cm) was significantly superior to all other genotypes including F_1 hybrids (0.81 cm). It was followed by D13 (0.85 cm), D3 (0.84 cm), D1 (0.83 cm) and D6 (0.83 cm). The pericarp thickness of genotypes D4 and D9 was at par with the susceptible control, D-check (0.61 cm). The pericarp thickness of D4 and D9 was the lowest (0.61 cm) indicating its probable susceptibility to fruit cracking. While thicker pericarp (i.e. more than 0.81 cm) resist the forces of fruit cracking.

4.1.3 Equatorial diameter of the fruit (cm)

The data presented in Table 1 show that the mean equatorial diameter of the fruit differ significantly ranging from 4.15 cm in genotype D11 to 4.93 cm in genotype D2. More significantly, it is observed that the genotypes with minimum equatorial diameter (i.e. D_{11}, D_{13}, D_3 and D_6) have recorded the least fruit cracking while the genotypes with greater equatorial diameter (i.e. D_4 and D_2) have recorded the highest fruit cracking. The equatorial diameter of the least-cracking genotype, D_{11} (4.15 cm) was at par with crack resistant control F_1 hybrid, Rajashree (4.13 cm) while, the equatorial diameter of the higher cracking genotype, D_2 (4.93 cm) was at par with the susceptible check (4.96 cm).

4.1.4 Polar diameter of the fruit (cm)

The data depicted in Table 1 reveal that the least mean polar diameter of the genotype D_{11} (4.47 cm) differed significantly with other genotypes. It was followed by D_{13} (4.51 cm), D_3 (4.61 cm) and D_4 (4.62 cm). The maximum polar diameter was observed in the genotype D_9 (5.07 cm).

4.1.5 Size of the fruit

Considering both diameters i.e. equatorial and polar, it was evident that the size of the fruit (equatorial diameter x polar diameter) also affected fruit cracking. In the moderate sized fruits, where minimum equatorial and polar diameter was recorded (i.e. in D_{11} - 4.15 x 4.47 cm), the least cracking was noticed (32.17 %). While in bigger sized fruits, where both diameters were of higher values (i.e. in D_4 - 4.90 x 5.05 cm), the severe cracking was observed (55.82 %).

4.1.6 Shape of the fruit

The ratio of equatorial to polar diameter represents the shape of the fruit. While considering the fruit shape the lowest cracking was recorded in genotypes D_{11} and D_{13}, where the ratio of equatorial to polar diameter is less (i.e. 0.93 in D_{11} and 0.95 in D_{13}).

4.1.7 Fruit weight (g)

Data regarding the mean fruit weight of the promising selections of cv. Dhanashree is presented in Table 1.

The character, fruit weight was varied significantly in different genotypes. The maximum fruit weight was obtained in the genotype D_9 (58.7 g) followed by D_4 (58.1 g), D_2 (57.9 g) and D_{10} (57.5 g). The minimum fruit weight was observed in 'genotype D_{11} (52.8 g). From Table 1 it was evident that minimum cracking was recorded in small fruited genotypes like D_{11} while maximum cracking was observed in large fruited genotypes such as D_4 and D_9.

4.1.8 Number of locules per fruit

Although character number of locules was varied non significantly, it is important to note that the genotypes (such as D_{11}, D_{13}, D_3 and D_6) which recorded minimum fruit cracking percentage (i.e. 32-37 %) had lower number of locules and *vice versa.*

4.1.9 Yield

The data regarding the yield (i.e. per plant and per hectare) of promising selections of cv. Dhanashree is represented in Table 1. However, it is important to note that when the crop was at full-bearing stage (i.e. 90 days after transplanting) the heavy rainfall (203.8 mm) on 22nd October, 1996 caused the severe damage to the crop and affeced the yield adversely. But due to sudden climatic change in the atmosphere, it created the most congenial conditions for fruit cracking. Particularly the yield of cvs. Dhanashree and Rajashree were the most affected, being semi-indeterminate growth habit and long harvesting period. There was comparatively less damage to the cv. S-28, being determinate growth habit and concentric harvest. Otherwise, the yield levels of cv. Dhanashree and Rajashree would be much higher than the reported in Table 1.

While comparing the yield levels in Table 1, the significant yield differences were noticed among the genotypes under study. The selection D_3 recorded the highest yield (421.57 q/ha) followed by the resistant F_1 cultivars S-28 (416.94 q/ha) and Rajashree (415.83 q/ha). It is important to note that the yields of the other selections such as D_1 (388.09 q/ha), D_9 (375.71 q/ha) and D_8 (368.00 q/ha) were at par with the check F_1 hybrids.

It is also worthy to note that all the promising selections have recorded more than one kilograms of fruit yield per plant. Thus, the high yielding potential of cv. Dhanashree is also observed in unusual climatic conditions. The major yield contributing characters observed in cv. Dhanashree were semi-indeterminate growth habit, excellent vegetative growth with fair number of primary branches (3-4), and dense foliage cover offered by broad leaf lamina (i.e. potato-type leaves), good fruit set (30-47 %), more number of fruits per plant (40-65) with moderate fruit weight (53-59 g) and fruit size (4.0 - 5.0 x 4.0 - 5.0 cm), (Refer ancillary data in Table 1).

4.2 Screening of isogenic lines of cv. Bhagyashree for radial fruit cracking

The data regarding the radial fruit cracking and other horticultural traits of eight selections from cv. Dhanashree along with cracking resistant control varieties is presented in Table 2.

4.2.1 Radial fruit cracking

It is observed from the data in Table 2 that all eight selections of cv. Bhagyashree have recorded significantly lower radial fruit cracking (27-42 %) over the check cultivar (i.e. Bhagyashree, fruit cracking - 59.17 %). However, the cracking resistant F_1 hybrid check varieties, performed significantly superior (20-22 % cracking) over the promising selections of cv. Bhagyashree. Among the selections of cv. Bhagyashree, the genotype B_7 recorded minimum cracking (27.13 %) followed by genotype B_6 (27.52 %) which recorded significantly lower fruit cracking over all other selections.

4.2.2 Pericarp thickness (cm)

The data depicted in Table 2 reveal that the mean pericarp thickness of the genotypes varied significantly. Among the selections of cv.

Table 2. Comparative performance of promising selections of cv. Bhagyashree for fruit cracking and other plant characters.

Selections	Fruit cracking (%)	Yield (q/ha)	Yield/ plant (g)	Fruit weight (g)	Equit'al diameter (cm)	Polar diameter (cm)	*Shape index	Pericarp thickness (cm)	TSS (%)	Height of plant (cm)	No.of branc-ches	Flowers per cluster	Fruits per cluster	Fruit set (%)	Days to 50 % flowering	No.of locules
B_1	38.49	287.09	898.00	73.27	5.58	5.70	0.98	0.58	3.13	59.60	4.20	8.87	3.07	34.69	78.73	5.13
B_2	31.40	318.45	1065.33	69.20	5.31	5.52	0.96	0.69	3.08	60.33	4.40	9.27	3.73	40.30	79.13	4.20
B_3	32.40	258.26	838.00	70.40	5.36	5.66	0.95	0.63	3.80	59.80	3.87	9.20	3.60	39.13	78.40	4.73
B_4	33.68	269.62	919.00	71.60	5.47	5.69	0.96	0.63	3.42	60.43	3.93	9.07	3.53	38.98	78.60	4.87
B_5	42.45	283.17	915.33	73.60	5.60	5.75	0.97	0.47	3.49	60.07	4.20	8.67	2.87	33.06	78.67	5.20
B_6	27.52	305.45	1014.66	68.20	4.99	5.42	0.92	0.69	3.10	60.40	4.00	9.33	3.87	41.44	79.00	4.13
B_7	27.13	274.48	858.66	67.73	4.97	5.22	0.95	0.73	3.09	59.87	4.20	9.40	4.07	43.27	78.93	3.80
B_8	36.85	404.55	870.67	72.66	5.57	5.66	0.98	0.59	3.42	59.97	4.20	8.93	3.53	39.56	78.53	4.67
B-check	59.17	278.59	906.66	73.67	5.50	5.76	0.95	0.48	3.91	60.73	4.07	8.87	2.93	33.07	78.80	5.27
Rajashree	20.62	414.63	1360.33	52.40	4.12	5.13	0.80	0.82	3.02	70.83	5.40	10.80	4.80	40.41	84.40	2.87
S-28	22.33	411.93	1334.00	52.67	4.16	4.65	0.89	0.81	3.80	70.63	5.33	10.73	4.73	44.12	84.40	3.00
General mean	33.82	318.75	998.24	67.76	5.10	5.47	0.94	0.65	3.39	62.04	4.34	9.38	3.70	39.28	79.78	4.35
S.E.m±	1.245	41.306	8.309	0.469	0.014	0.017	-	0.009	0.009	0.934	0.078	0.088	0.098	1.193	0.265	0.105
CD at 5%	3.671	N.S.	24.507	1.383	0.042	0.051	-	0.027	0.026	2.756	0.229	0.260	0.290	3.520	0.781	0.309

* Shape index = Equatorial diameter/Polar diameter

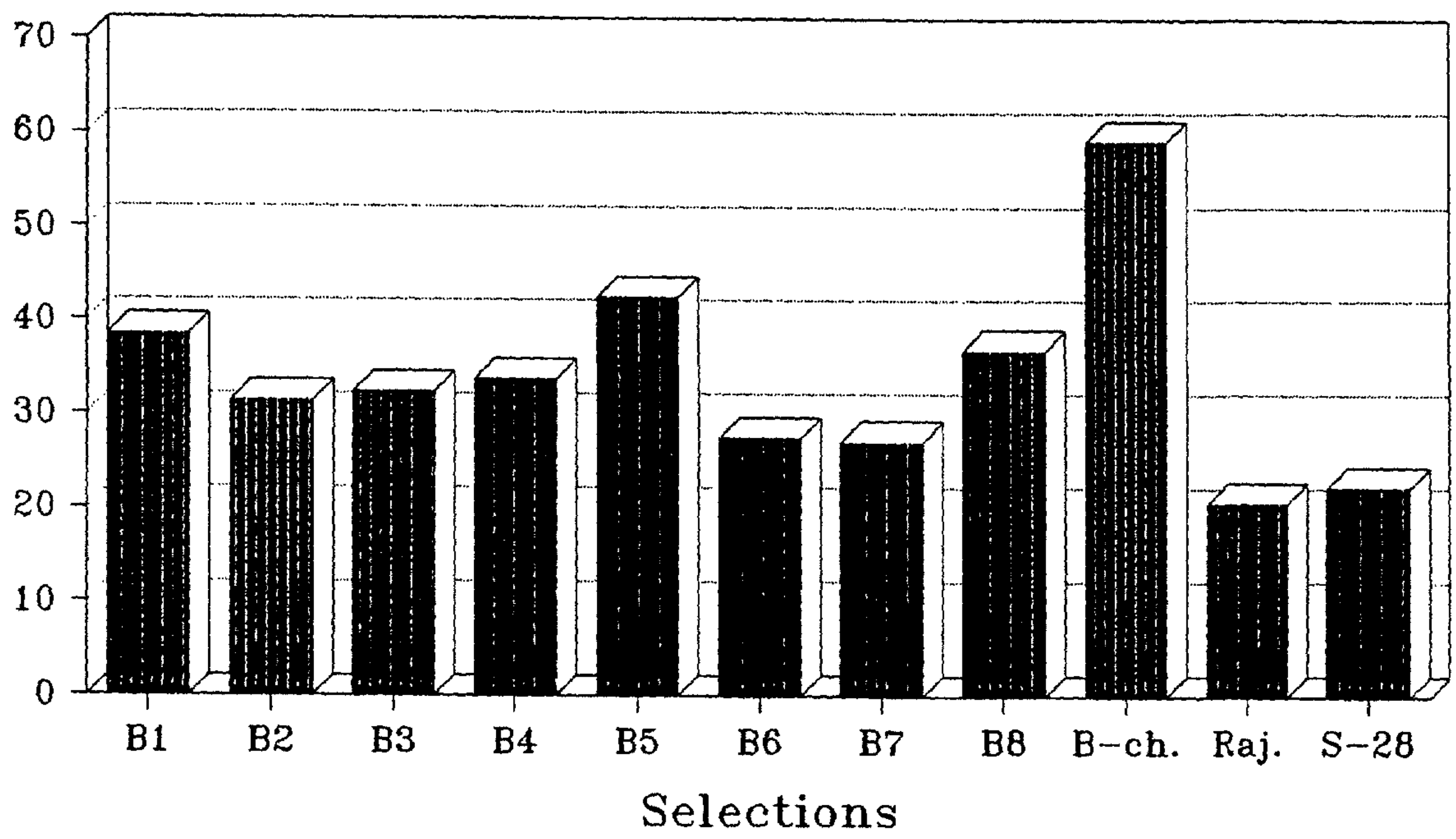


Fig.3. Comparative performance of promising selections of cv.Bhagyashree for fruit cracking

Bhagyashree, the maximum pericarp thickness was observed in the genotype B_7 (0.73 cm) which was significantly thicker over all other selections in the study. Other promising selections were B_6 (0.69 cm), B_2 (0.69 cm), B_4 (0.63 cm), B_3 (0.63 cm) and B_8 (0.59 cm) in the decreasing order. All these selections were superior over control B-check. But the control F_1 hybrids, Rajashree and S-28 (0.82 cm and 0.81 cm respectively) had significantly thicker pericarp than all the promising selections of cv. Bhagyashree. The minimum pericarp thickness of B_5 (0.47 cm) coincided with the highest cracking percentage (42.45 %) and similarly, maximum pericarp thickness of B_7 (0.73 cm) coincided with the minimum cracking (27.13 %).

4.2.3 Equatorial diameter of the fruit (cm)

The data pertaining to the mean equatorial diameter of the fruit is presented in Table 2. It is observed that the equatorial diameter of the fruit varied significantly in all the genotypes. The highest equatorial diameter was recorded in selection B_5 (5.60 cm) followed by B_1 (5.58 cm) and B_8 (5.57 cm) which were at par with each other and significantly superior over remaining genotypes including control cultivars. It is important to note that the selections B_7 and B_6 recorded the smaller equatorial diameter (4.97 and 4.99 cm respectively) and suffered minimum fruit cracking (27.00 %).

4.2.4 Polar diameter of the fruit (cm)

The data regarding the mean polar diameter of the fruit is presented in Table 2. It is evident that the character, polar diameter varied significantly. The control cultivar, Bhagyashree, recorded maximum polar diameter (5.76 cm) which was at par with selection B_5 (5.75 cm), and significantly greater than remaining genotypes. However, maximum fruit cracking was recorded in these two genotypes (59.17 and 42.45 %, respectively).

check (i.e. original cultivar) which recorded the maximum fruit cracking (59 %). On the contrary, the genotypes such as Rajashree, S-28 and B-7 which recorded minimum fruit cracking (i.e. 20, 22 and 27 %, respectively) had least number of locules (2.87, 3.00 and 3.80, respectively).

4.2.9 Yield

The unusual climatic conditions also hampered the yields of cv. Bhagyashree and its selections, as previously explained in 4.1.8 for cv. Dhanashree. In general, the yield potential of cv. Bhagyashree is comparatively lower than cv. Dhanashree. However, although the cv. Bhagyashree had recorded significantly lower yield (278 q/ha) than the F_1 hybrids, Rajashree (414 q/ha) and S-28 (411 q/ha); the selection B_8 recorded quite higher yield (404 q/ha) which was comparable with the F_1 hybrids.

Furthermore, the selections of cv. Bhagyashree also recorded more than 800 gm fruit yield per plant, which is a satisfactory yield level for open-pollinated cultivar. The major yield contributing characters in cv. Bhagyashree were also similar to cv. Dhanashree except the fruit size and fruit number. In cv. Bhagyashree bigger sized fruit (5.60 x 5.75 cm and 75 g weight) were observed but they were lower in number (30-40).

4.3 Selection improvement over the population

The further selection improvement over the population was also carried out by selecting individual plants having crack-free fruits from the population of selected genotypes under study. Because of heavy rainfall at full fruiting stage that created the most congenial condition for fruit cracking and it resulted into the maximum fruit cracking in the field.

From the severely affected plant population, the promising individual plants were selected and fruit cracking of the individual selection was compared against the population mean. It gave an opportunity to apply the

Table 3a. Performance of individual promising selections of cv. Dhanashree against the population of selection progeny for fruit cracking resistance.

Sr. No.	Promoising selections of cv. Dhanashree	Fruit cracking (%)
1.	D-1-1	16.66
2.	D-1-2	11.11
	D_1 population mean	38.02
3.	D-3-1	9.09
4.	D-3-2	3.79
	D_3 population mean	37.94
5.	D-6-1	6.08
6.	D-6-2	0.00
7.	D-6-3	16.66
	D_6 population mean	37.96
8.	D-7-1	7.69
9.	D-7-2	13.33
	D_7 population mean	48.38
10.	D-11-1	6.18
11.	D-11-2	9.09
	D_{11} population mean	32.17
12.	D-13-1	7.69
13.	D-13-2	4.27
	D_{13} population mean	37.37

Table 3b. Performance of individual promising selections of cv. Bhagyashree against the population of selection progeny for fruit cracking resistance.

Sr. No.	Promoising selections of cv. Bhagyashree	Fruit cracking (%)
1.	B-1-1	3.79
2.	B-1-2	9.09
3.	B-1-3	6.08
	B_1 population mean	38.49
4.	B-2-1	16.66
	B_2 population mean	31.40
5.	B-3-1	0.00
	B_3 population mean	32.40
6.	B-5-1	7.69
7.	B-5-2	13.11
	B_5 population mean	42.45
8.	B-6-1	4.27
9.	B-6-2	7.69
	B_6 population mean	27.52
10.	B-7-1	0.00
	B_7 population mean	27.13

rigorous selection pressure on the population. The data regarding the per cent fruit cracking in the 23 individual plant selections, 13 from cv. Dhanashree and 10 from cv. Bhagyashree, is presented in Tables 3a and 3b, respectively.

The data from Tables 3a and 3b reveal that the fruit cracking percentage in all selected plants was significantly lower than the population mean. It showed the remarkable genetic gain over the population and promise for further screening. In cv. Dhanashree, thirteen individual selections were made from six families (i.e. D_1, D_3, D_6, D_7, D_{11} and D_{13}). The population mean for these six families was ranging from 32-48 per cent fruit cracking. However, the selection mean, ranging from 0-16 per cent fruit cracking, was significantly lower than cracking resistant F_1 hybrids (20-22 %). It is worthy to note that the selection D-6-2 was found totally crack-free followed by selections D-3-2 (3.79 %), D-13-2 (4.27 %), D-6-1 (6.08 %), D-11-1 (6.18 %), D-7-1 (7.69 %) and D-13-1 (7.69 %). Thus, these eight selections from cv. Dhanashree which recorded the least fruit cracking (0-7.67 %) showed promise for further genetic improvement.

Also in cv. Bhagayshree, significantly lower fruit cracking was observed as a selection mean (0-16 %) in comparison with the population mean (27-42 %). From cv. Bhagyashree, six selections were found most promising for radial fruit cracking. Two selections (B-3-1 and B-7-1) were observed to be completely crack-free (0 %) while selections B-1-1, B-6-1, B-1-3, B-6-2 and B-5-1 recorded the least fruit cracking (i.e. 3.79, 4.27, 6.08, 7.69 and 7.69 %, respectively).

4.4 Genetic parameters

Genetic parameters such as phenotypic, genotypic and environmental variances, coefficient of variations heritability and expected genetic advance were calculated (Table 4 and 5).

Table 4. Estimation of phenotypic, genotypic and environmental variances of cv. Dhanashree and cv. Bhagyashree.

Sr. No.	Characters	Variances		
		Phenotypic	Genotypic	Environmental
1.	Fruit cracking			
	a. Dhanashree	124.791	121.000	3.791
	b. Bhagyashree	117.770	113.120	4.650
2.	Pericarp thickness			
	a. Dhanashree	0.010	0.009	0.000
	b. Bhagyashree	0.014	0.013	0.000
3.	Equatorial diameter			
	a. Dhanashree	0.092	0.089	0.003
	b. Bhagyashree	0.286	0.285	0.001
4.	Polar diameter			
	a. Dhanashree	0.047	0.046	0.001
	b. Bhagyashree	0.119	0.118	0.001

Table 5. Genotypic and phenotypic coefficient of variation, heritability and expected genetic advance of cv. Dhanashree and cv. Bhagyashree

Sr. No.	Characters	Genotypic coefficient of variation GCV (%)	Phenotypic coefficient of variation PCV (%)	Heritability (%)	Expected genetic advance (EGA)
1.	Fruit cracking				
	a. Dhanashree	26.35	26.76	96.96	22.13
	b. Bhagyashree	31.45	32.09	98.01	21.47
2.	Pericarp thickness				
	a. Dhanashree	13.12	13.32	96.94	0.20
	b. Bhagyashree	17.96	18.16	97.83	0.24
3.	Equatorial diameter				
	a. Dhanashree	6.55	6.66	96.74	0.60
	b. Bhagyashree	10.47	10.49	99.65	1.10
4.	Polar diameter				
	a. Dhanashree	4.48	5.53	97.87	0.44
	b. Bhagyashree	6.28	6.31	99.16	0.71

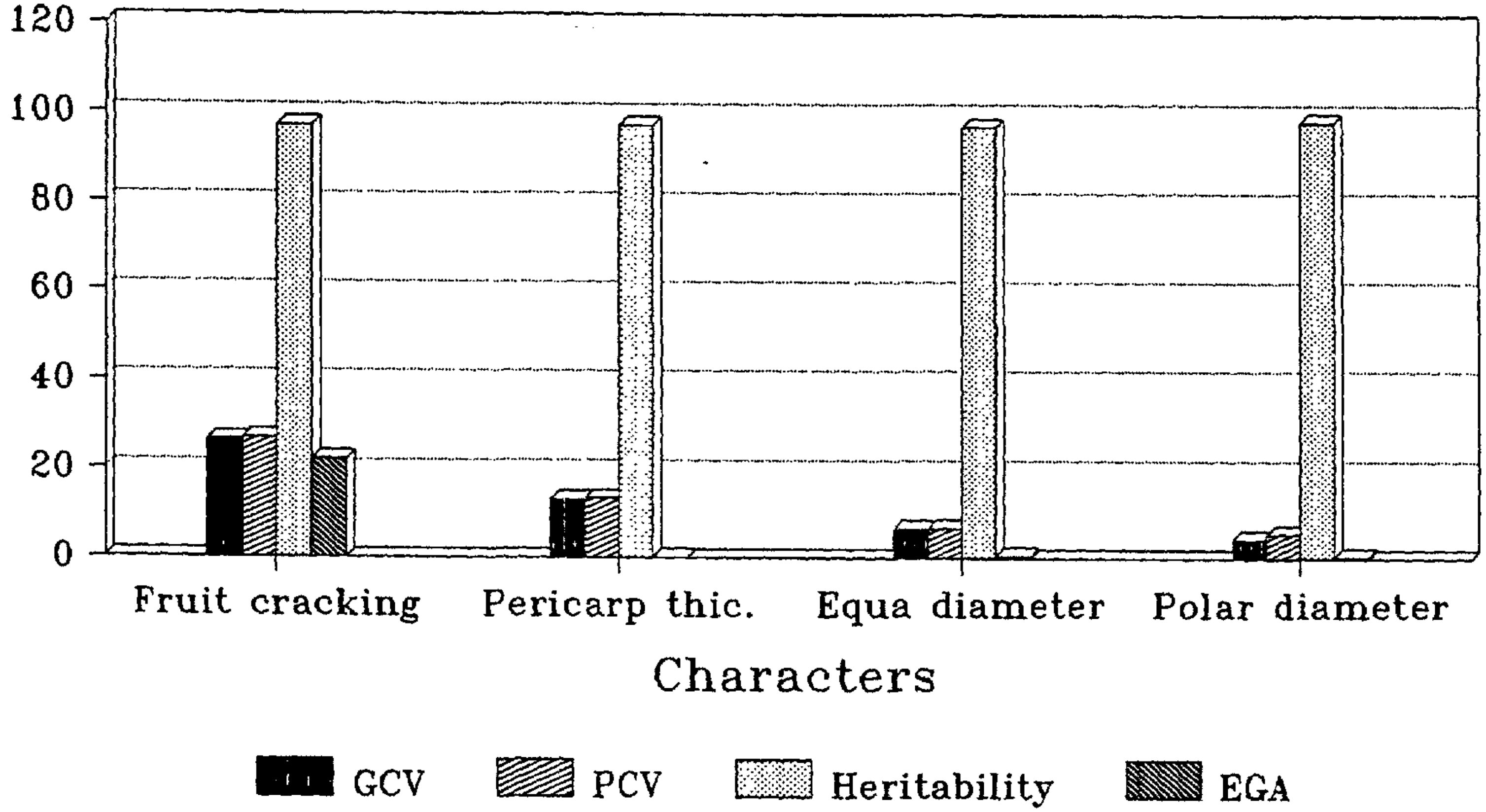


Fig.4.Genotypic & phenotypic coefficient of variation,heritability & expected genetic advance of cv.Dhanashree

4.4.1 Phenotypic, genotypic and error variances

The data in the Table 4 reveal that for all characters, higher values were recorded for phenotypic variances followed by genotypic variances and lower values were recorded for environmental variances. It is worthy to note that, in both the cultivars, the maximum phenotypic and genotypic variances were observed for the important character, fruit cracking, while comparatively lower variances were observed in other characters, such as equatorial and polar diameter and pericarp thickness.

4.4.2 Phenotypic and genotypic coefficients of variation

While considering the coefficients of variation, maximum values were found for phenotypic coefficient of variation (PCV) compared to genotypic coefficients of variation (GCV) for all characters in both the cultivars (Table 5). For cvs. Dhanashree (D) and Bhagyashree (B), the maximum coefficients of variation were observed for the important characters such as radial fruit cracking (PCV - 26.76% for D and 32.09 % for B; GCV - 26.35 % for D and 31.45 % for B) followed by pericarp thickness (PCV - 13.32 % for D and 18.16 % for B; GCV - 13.12 % for D and 17.96 for B), followed by equatorial diameter (PCV - 6 and 10 % respectively, GCV - 6 %) and polar diameter (PCV - 5 and 6 % respectively; GCV - 4 and 6 % respectively).

4.4.3 Heritability and expected genetic advance (EGA)

In both cvs. Dhanashree and Bhagyashree, very high estimates (i.e. > 96 %) were observed for heribability for all four characters (Table 5). However, moderately higher genetic advance was noticed only for the character, fruit cracking (22.13 for cv. Dhanashree and 21.47 for Bhagyashree). While for other characters negligible (i.e. < 1 %) EGA was recorded.

Table 6. Effect of boron application on radial fruit cracking and other horticultural traits in tomato : cv. Dhanashree

Treatments	Fruit cracking (%)	Yield (q/ha)	Yield/ plant (g)	Fruit weight (g)	Equit'al diameter (cm)	Polar diameter (cm)	Pericarp thickness (cm)	TSS (%)	Height of plant (cm)	No.of branc-ches	Flowers per cluster	Fruits per cluster	Fruit set (%)	Days to 50 % flowering	No.of locules
T_1	20.81	365.46	1150.20	62.08	4.86	5.04	0.87	4.11	68.12	4.24	10.76	4.36	40.54	84.80	3.00
T_2	16.55	377.51	1166.00	62.80	5.01	5.12	0.92	4.16	68.08	4.32	11.56	4.80	41.65	84.76	3.00
T_3	19.50	368.14	1160.00	62.32	4.90	5.05	0.87	4.12	68.08	4.28	10.76	4.44	41.30	84.84	3.04
T_4	45.01	357.80	1137.20	58.92	4.79	4.99	0.80	3.93	68.12	3.84	10.36	3.84	37.05	84.80	3.08
Gene.Mean	25.47	367.23	1153.40	61.53	4.89	5.05	0.87	4.08	68.10	4.17	10.86	4.86	10.13	84.80	3.03
S.Em.±	0.656	1.848	5.335	0.137	0.017	0.009	0.008	0.007	0.210	0.122	0.128	0.067	0.518	0.107	0.062
CD at 5%	2.022	5.697	16.445	0.424	0.053	0.028	0.024	0.022	N.S.	N.S.	0.394	0.206	1.597	N.S.	N.S.

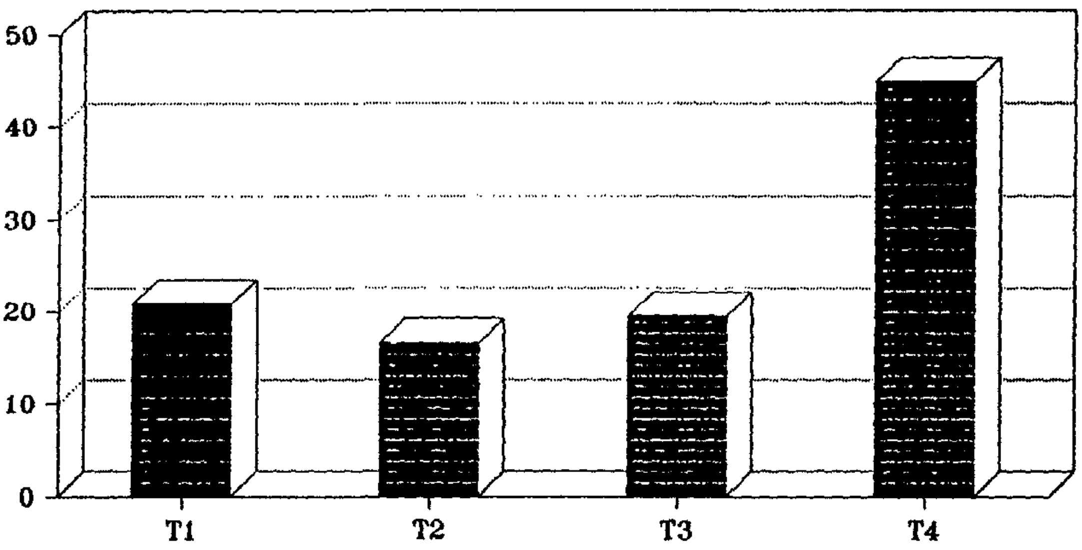


Fig.5.Effect of different treatments of boron on fruit cracking in tomato cv. Dhanashree

4.5 Effect of boron application on radial fruit cracking and other horticultural characters in cv. Dhanashree

Boron was applied as soil application (15 kg/ha), foliar spray (0.25 %) and combination of both, as a supplementary micronutrient dose to overcome the problem of radial fruit cracking. The results are summarised in Table 6.

4.5.1 Fruit cracking (%)

The data pertaining to the effect of different treatments of boron on fruit cracking is presented in Table 6. The data reveal that the minimum percentage of fruit cracking (16.55 %) was observed in treatment, T_2 (soil + foliar application) which was significantly superior over other treatments. It was followed by 19.50 per cent cracking in treatment, T_3 (foliar spray) and 20.81 per cent in treatment, T_1 (soil application), which were at par with each other. The control, T_4 (no boron application) showed maximum fruit cracking (45.01 %) which was significantly higher to all boron treatments.

4.5.2 Pericarp thickness (cm)

The data presented in Table 6 showed that the pericarp thickness of tomato fruits in treatment T_2 (0.92 cm) was significantly more than other treatments. Both treatments T_1 and T_3 produced fruits with the pericarp thickness of 0.87 cm. All the three boron treatments T_1, T_2 and T_3 responded well to produce thicker fruit pericarp than those of control fruits (0.80 cm).

4.5.3 Equatorial diameter of the fruit (cm)

The data in Table 6 showed that the equatorial diameter differed significantly and ranged from 4.79 cm in treatment 4 (control) to 5.01 cm in treatment 2. The treatments T_1 and T_3 recorded intermediate values for equatorial diameter i.e. 4.86 and 4.90 cm respectively.

4.5.4 Polar diameter of the fruit (cm)

The data in Table 6 reveal that polar diameter of fruit differed significantly, with the maximum value (5.12 cm) in treatment T_2 followed by T_3 (5.05 cm), T_1 (5.04 cm) and T_4 (4.99 cm) in the decreasing order.

4.5.5 Total soluble solids (%)

The data depicted in the Table 6, reveal that the TSS content in treamtment T_2 (4.16 %) wass significantly higher than all other treatments, followed by treatments T_3 (4.12 %) and T_1 (4.11 %). The per cent TSS in T_4 (3.93 %) was the lowest of all treatments.

4.5.6 Fruit weight (g)

The data regarding fruit weight (Table 6) reveal that the maximum fruit weight (62.80 g) was observed in treatment T_2 which is significantly more over all other treatments. The mean fruit weight of treatments T_3 (62.32 g) and T_1 (62.08 g) were at par with each other. The treatment T_4 (58.92 g) has minimum fruit weight.

4.5.7 Yield

The data in Table 6 showed that significant variations were observed for yield per hectare and yield per plant due to treatment differences. The significant highest yield (377 q/ha and 1166 g/plant) was recorded by the treatment T_2, where boron is applied as soil application combined with foliar application. It was followed by the treatment T_3 i.e. foliar application (368 q/ha and 1160 g/plant) and T_1 i.e. soil application (365 q/ha and 1150 g/plant) which were at par with each other and recorded significantly higher yield over control i.e. T_4 (357 q/ha and 1137 g/plant).

The yield levels in boron treatments were increased as a result of improvement in yield contributing characters such as fruit weight, fruit size and fruit set. However, boron application could not influence the characters like plant height, number of branches, days to 50 per cent flowering and number of locules in the fruit. Nevertheless, boron application had significantly increased the TSS content of fruit.

DISCUSSION

5. DISCUSSION

In present investigation, the radial fruit cracking in tomato for *Kharif* season was studied genetically as well as agronomically. In genetical studies, the promising selections (13 of cv. Dhanashree and 8 of cv. Bhagyashree) were screened for fruit cracking with a susceptible (original cultivar) and resistant (two F_1 hybrids i.e. Rajashree and S-28 showing least fruit cracking) controls. For agronomical studies, an effect of boron was assessed through soil, foliar and in combined application on radial fruit cracking in tomato cv. Dhanashree. The results obtained are discussed under the appropriate heads.

5.1 Variation in per cent fruit cracking

The cv. Dhanashree and cv. Bhagyashree are released by M.P.K.V., Rahuri in 1992. The salient features of these cultivars are high yielding, rich in qualitative traits (lycopene content, TSS, vitamin C content, fruit juice and titrable acidity, taste, flavour etc), moderate shelf life (6-8 days) and field tolerance to viral diseases. Therefore, these tomato cultivars are adopted by small farmers for local markets.

But the incidence of radial fruit cracking in *kharif* season reduced its marketable yield. Therefore, the assessment of the promising selections of these two cultivars for fruit cracking resistance was the important objective in the tomato breeding programme for variety improvement.

In the present investigation significant differences in radial fruit cracking were observed in the selections of both the cultivars Dhanashree and Bhagyashree. The range of variation in selections of cv. Dhanashree was 32-55 per cent while, it was 27-42 per cent for selections of cv. Bhagyashree; which was significantly less than the susceptible check but more than the resistant control varieties. Due to the most congenial climatic conditions in *kharif* (1996) i.e. long dry and hot spell followed by heavy rainfall, the severe fruit cracking was noticed in all the genotypes of tomato including the resistant control F_1 hybrids. These results are in confirmity with Frazier (1934), Kamimura *et al.* (1972), Murase (1981) and Peet and Willits (1995). Generally, severe cracking occurs during high day temperatures and low night temperatures from mid-may onwards (Drews, 1978). Also heavy rain increases the relative humidity (RH > 80 %) and such sudden change in relative humidity resulted in severe fruit cracking (Drews, 1978; Outer, 1987 and Ohta *et al.*, 1991).

5.2 Radial fruit cracking as genetical studies

Though the climatic conditions and agronomic practices for all the genotypes were same, there were significant differences in fruit cracking of different genotypes. This lead us to conclude that there is a genetical control for fruit cracking which makes the genotype resistant or susceptible to fruit cracking. It is in confirmity with Young (1959) who reported that radial cracking was under genetical control and inherited genetically.

5.3 Study of genetical parameters for radial fruit cracking

5.3.1 Genotypic and phenotypic coefficient of variation

The highest genotypic and phenotypic coefficients of variation (GCV and PCV) were observed for per cent fruit cracking followed by pericarp thickness. It was observed that PCV were of higher magnitude than that of GCV though similar trends were observed at both genotypic and phenotypic levels. Thus, it can be concluded that variability present in plant population is mostly genetical and these characters can be improved through breeding programme.

5.3.2 Heritability and genetic advance

Genotypic coefficient of variation gives the little idea of the total variation that is heritable. The relative amount of heritable portion of variation can be assessed through suitable heritability estimates. The high heritability indicates the effectiveness of selection based on phenotypic performance, but does not necessarily mean a high genetic gain for particular trait. The character with high heritability estimates associated with high genetic gain may be attributed to the additive gene effects, which can be easily improved by selection. On the other hand, high heritability and low genetic advance may be attributed to the non-additive gene effects. These characters may be improved through hybridization. Low heritability estimates suggested that selection for the character under consideration will not be effective. Through genotypic coefficient of variation, the heritable variation cannot be estimated and as such genotypic coefficient of variation together with heritability would furnish the most reliable information on the magnitude of genetic advance to be expected from selection.

In present studies, for character radial fruit cracking, very high estimates are observed for heritability (i.e. >96 %) and also for genetic advance (> 21). It gives clear idea that this particular character is under additive gene action and can be improved by the simple selection method. These results are in confirmity with the findings of Hepler (1961). However, according to Prasher and Lambeth (1960), Young (1962), Armstrong and Thompson (1967) and Chu and Thompson (1971), the radial fruit cracking is a polygenic character and have pleiotrophic effect and interallelic interaction.

However, other associated characters such as pericarp thickness and fruit size (i.e. equatorial and polar diameter) are under non-additive gene action, as higher estimates of heritability (> 96 %) are accompanied with lower genetic advance (< 1). Hence, these traits need hybridization programme for effective improvement.

5.4 Genetical improvement of selections over the population for radial fruit cracking

Promising results of the selection improvement over population (refer 4.3 and Table 3) proves that the selection pressure is definitely effective because the selected plants showed outstanding superiority over the population for radial fruit cracking resistance. More importantly, the particular individual selections, D-6-2 in cv. Dhanashree and B-3-1 and B-7-1 in cv. Bhagyashree have been found totally crack-free. All the 23 selections have found to be superior over the crack-resistant F_1 hybrids, Rajashree and S-28. It clearly indicates the effective genetic improvement of radial fruit cracking through selections.

All these promising genotypes, especially D-6-2, B-3-1 and B-7-1, should be utilised in the further breeding programme for improvement against the fruit cracking. Although environmental factors influences fruit cracking in tomato, with the genetical control it is possible to keep the problem to the minimum level.

5.5 Effect of other fruit characters on occurance of fruit cracking

The results reveal that there is significant effect of various fruit characters on the occurance of fruit cracking.

The pericarp thickness of fruit is one of the important characters having significance for cracking resistance. It is clearly observed that the maximum pericarp thickness of the fruit is prevalent in the genotype with minimum fruit cracking (i.e. 0.85 cm in D_{11} and 0.73 cm in B_7) and the thinnest pericarp is observed in the genotype with maximum fruit cracking (i.e. 0.61 cm in

D_4 and 0.47 cm in B_5). Thus these results are in agreement with those obtained by Faust and Shear (1972) who reported that thin pericarp of the fruit is susceptible to fruit cracking. This may be due to the fact that thick pericarp is able to withstand the increased internal pressure created by dividing cells or absorbed water. And such fruit skins are more elastic which can expand on sudden swelling and thus resist cracking (Nueuchi and Handa, 1961 and Janse, 1985).

The character fruit size (i.e. equatorial and polar diameter) is also important consideration. In our results, moderately smaller fruited selections of both cultivars Dhanashree and Bhagyashree [D_{11} (4.15 x 4.47 cm) and B_7 (4.97 x 5.22 cm) respectively] had minimum percentage of fruit cracking. These results are in confirmity with Young (1959) who reported that the resistance to cracking is associated with small fruit size. It is also supported by Frazier (1934) with the conclusion that small fruits resist the cracking by skin elasticity while bigger fruits get susceptible due to increased mechanical stress on epidermis.

The characters, equatorial and polar diameter are not only responsible for fruit size but it also decides shape of fruit; when equatorial and polar diameters are of equal dimensions, the fruit shape is perfect round. When equatorial diameter is more than polar diameter, it gives flat shape to the fruits. While when the polar diameter exceeds equatorial diameter, it results into oblong fruit shape. The influence of various fruit shapes is also noticed on fruit cracking. The fruits having round to flat shape are more susceptible to fruit cracking as compared to oblong or pear shaped fruits. In roundish or flatish fruits, the surface tension is higher at full maturity stage and it result into fruit cracking. However, in pear shaped fruits comparatively lower fruit cracking can be explained as there is lower surface tension and more surface area is available for expansion of pericarp tissues.

The character fruit weight also influences fruit cracking. The minimum fruit weight was found in D_{11} (52.80 g) and B_7 (67.73 g), which also recorded least fruit cracking. The fruit weight is linked with the size of the fruit. Therefore, severe fruit cracking is observed with bigger sized round or flat fruits associated with heavy fruit weight and *vice-versa*.

Similarly, the TSS content may affect the fruit cracking. But in the present studies it was found that the TSS does not correlate with the fruit cracking and is unrelated, since, the TSS content in the most crack susceptible (D_4) and resistant (D_{11}) genotypes was at par with each other.

The character, number of locules in the fruits seems to affect fruit cracking in tomato. In crack-resistant F_1 hybrid, check varieties minimum number of locules (< 3.0) is recorded. While in selections of cv. Dhanashree and cv. Bhagyashree, severe cracking is observed in genotypes (i.e. D-check, D_4, D_{10}, D_7 and B-check) having more number of locules ($\geq$ 3.0) and least cracking is recorded in genotypes (e.g. D_{11}, D_3, D_6 and B_7) with the fewer locules in the fruits. These results are comparable with the findings of Young (1959), who reported that the resistance of fruit cracking is associated with low number of locules per fruit. This may be due to the fact that less number of locules (i.e. less septa) gives more space for expansion of fruit epidermis.

5.6 Effect of boron application on fruit cracking and other characters

Besides genetical improvement, the fruit cracking in tomato can also be controlled agronomically by the supplement of boron. Hence, the experiment was conducted by various applications of boron (soil, foliar and combination) to control radial fruit cracking in tomato. The results are discussed briefly under appropriate titles.

5.6.1 Effect of boron application on fruit cracking in tomato

Perusal of the results (in 4.5 Table 6) disclose that the fruit cracking, in all applications of boron (i.e. soil, foliar and combination of the two), was significantly lower than the untreated control plots. These results are in agreement with Kalloo (1985) who recommended the application of borax either to soil (10-15 kg/ha) or as foliar spray (0.25 %) for control of fruit cracking in tomato.

Furthermore, it is observed that the combination of soil application and foliar spray is more effective in control of fruit cracking than either of single treatments. Nevertheless, in comparision between foliar spray and soil application of borax, in present study, the foliar spray was found to be superior. Similar results are obtained by Pais and Hodossi (1976) in tomato; Shorrocks and Nicholson (1979) and Wundermann (1981) in apple; Singh *et al.* (1990) in pomegranate and Chandel and Ganesh (1995) in litchi.

In present study, all the boron treatments are found to be effective in controlling fruit cracking in tomato because boron is essential to maintain the structural integrity of plant cell membrances while its deficiency changes the membrane permeability (Pilbeam and Kirkby, 1983). Also, Maynard *et al.* (1959) concluded that cracking in tomato occurs as a result of rupture of thin-walled collenchyma cells due to deficiency of boron, while advancing the maturity. Boron also might be effective, because it plays important role in translocation of calcium, an important component of cell wall and its metabolism in cell wall (Yamauchi *et al.*, 1986). More cracking in untreated fruits may be because of disintegration of cambium cells due to deficiency of boron (Katherine, 1926).

5.6.2 Effect of boron application on other characters

The result, regarding effect of boron on pericarp thickness shows more pericarp thickness in combination of soil and foliar application, and lower in control plots. Also, individual soil and foliar applications, are equally effective. The thicker pericarp in boron treated fruits may be due to boron essentiality in calcium metabolism and also its translocation to the cell walls. Boron increases the association of calcium with pectin constituents (Yamauchi *et al.* 1986). Boron is essential to maintain the structural integrity of plant cells and affects its permeability (Pilbeam and Kirkby, 1983). Hence the least cracking is observed in the boron treated fruits having thick pericarp.

Fruit size (equatorial x polar diameter) is also significantly increased due to boron treatments. These results are in close confirmity with the results of Mei *et al.* (1984). Although in earlier results of genetical improvement the bigger fruit size is proved more susceptible to fruit cracking, in this experiment supplement of boron may help to control cracking in bigger fruits.

More interestingly, total soluble solid (TSS) content in boron treated fruits is found significantly more than untreated fruits. These results show confirmity with the results of Arora *et al.* (1982). Increase in TSS might be the result of more supply of assimilates due to stimulative effect of boron. This will be an important consideration for the processing industries.

Results pertaining to the fruit weight shows a significant increase by application of boron than untreated fruits, though there is much difference in fruit weight of three treatments. These results have supported the findings of Mei *et al.* (1984), however, are in contrast with the report of Agwah and Mahmoud (1994) who observed that the application of 0.25 per cent borax decreases the fruit weight.

Yields (per plant and per hectare) of boron treated plots were significantly more than untreated plots. The highest tomato fruit yield was observed in combined application followed by foliar and soil application.

Dzhavakhishvili and Egorashvili (1985) has also reported 15 per cent increase in yields in tomato with combined treatment, followed by 11 per cent increase by foliar application; these findings support our results. Increase in tomato fruit yield

due to boron application is also noticed by Pandita *et al.* (1979), Das and Das (1981), Castellane *et al.* (1982), Singh *et al.* (1990), Ghanta and Mitra (1993), Agwah and Mahmoud (1994) and Chandel and Ganesh (1995).

The results regarding the effect of boron on increased fruit set in tomato show positive relationship with increase in yield. The increased fruit set was also noticed by Agwah and Mahmoud (1994) and Pandita *et al.* (1979).

Thus, the important yield contributory characters responsible for increasing yields are observed as fruit weight, fruit size, fruit set and fruit yield per plants. Similar observations were noticed by Mei *et al.* (1984) while evaluating an effect of boron on tomato cultivation.

SUMMARY AND CONCLUSIONS

6. SUMMARY AND CONCLUSIONS

A field experiment entitled "Studies on radial fruit cracking in tomato (*Lycopersicon esculentum* Mill.)" was conducted at the Department of Horticulture, M.P.K.V., Rahuri during the *kharif* season of 1996. Genetical as well as agronomical studies were undertaken to overcome the problem.

For genetical studies cv. Dhanashree and cv. Bhagyashree, an open pollinated varieties, developed by M.P.K.V., Rahuri for fresh market and processing were involved. The 13 and 8 promising selections of cv. Dhanashree and cv. Bhagyashree respectively, already developed by the Tomato Improvement Project, Department of Horticulture, M.P.K.V., Rahuri, were screened for cracking resistance. For cv. Dhanashree and cv. Bhagyashree, two separate experiments were conducted along with the two checks; crack susceptible check used as an original cultivar while for crack resistant check, two F_1 hybrids (i.e. Rajashree and S-28) were included, which especially bred for excellent keeping quality and showed maximum cracking resistance. For agronomical studies, an effect of boron on fruit cracking was evaluated through three different applications : soil application of Borax @ 15 kg/ha (T_1), Foliar spray of 0.25 per cent borax (T_3) and combination of soil and foliar treatment (T_2).

While undertaking the genetical studies for screening of promising selection of cv. Dhanashree and cv. Bhagyashree for cracking resistance, it is observed that significant lower fruit cracking (27-42 %) was recorded by most of the promising selections over the original variety (58-59 %); but it was significantly more than that of crack resistant F_1 hybrids (20-22 %). Among 13 genotypes of cv. Dhanashree, the D-11 was the most promising progeny with the minimum (32.17 %) fruit cracking. However, in cv. Bhagyashree, among the 8 genotypes, two families (B_7 and B_6) recorded outstanding results with the least fruit cracking (i.e. 27 %). Because of the most congenial climatic conditions in *kharif* 1996, the fruit cracking was at the peak and crack resistant F_1 hybrids also recorded 20 per cent fruit cracking.

While screening the progeny of promising genotypes of cv. Dhanashree and cv. Bhagyashree for cracking resistance, an individual selection pressure was also applied for further genetical improvement and selection mean was compared with population mean. In this regard, thirteen individual plants from cv. Dhanashree and ten individual plants from cv. Bhagyashree were selected and remarkable genetic gain was observed over population with 0-16 per cent fruit cracking as a selection mean over 27-55 per cent fruit cracking as a population mean. More importantly, a selected plant, D-6-2 from cv. Dhanashree and two individuals, B-3-1 and B- 7-1 from cv. Bhagyashree were found to be completely crack-free and thus these three individuals will be assessed in further breeding programme to confer the crack resistance in cvs. Dhanashree and Bhagyashree.

While studying the genetical parameters, the maximum genetic variability was observed for the character fruit cracking followed by pericarp thickness, equatorial diameter and polar diameter. However, high estimates of heritability and genetic advance was only recorded in the character, fruit cracking and thus it can be concluded that the character, fruit cracking is under additive gene action and can easily be improved by the simple selection method.

While evaluating the effect of boron on tomato fruit cracking as an agronomical studies, it is observed that all three boron applications found effective as significant lower fruit cracking is recorded than the control (45 %). The boron treatment with combination of soil application and foliar spray was found the most effective one with the least fruit cracking percentage (16.55 %)

as compared to individual treatment of foliar spray (19.50 %) or soil application (20.81 %). It is important to note that boron application not only reduces the fruit cracking but also increase the yield levels through increasing fruit set, fruit size and weight. Qualitative traits such as pericarp thickness and TSS content are also improved by boron application.

Briefly, the result can be concluded as follows :

I. Genetical studies shows promise to the varietal improvement for fruit cracking resistance.

1. Among the 13 genotypes of cv. Dhanashree, the genotype D_{11} was most resistant to fruit cracking while D_4 was found most susceptible.
2. Among the 8 genotypes of cv. Bhagyshree the B_7 and B_6 are identified as promising genotypes for crack resistance.
3. Selection improvement over population is noticed for fruit cracking as selection mean of individual selected plants was significantly lower than the population mean of promising genotype and also over resistant check cultivars. Furthermore, three individual plants are identified as completely crack-free.
4. Radial fruit cracking is under genetic control of additive gene action and can be improved by simple selection method.

II. Top dressing with boron application can significantly reduce the radial fruit cracking in susceptible tomato cultivar

1. Combine treatment of boron with soil application and foliar spray is found most effective in controlling radial fruit cracking followed by foliar spray and soil application.
2. Boron also improved quantitative and qualitative traits in tomato.

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7. LITERATURE CITED

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*** Originals are not seen**

APPENDIX

Appendix : Meteorological data recorded during the experimental period (June 1996 to October 1996)

Meteoro-logical week	Date	Mean temperature (^{O}C)		Relative humidity (%)		Rainfall (mm)	Rainy days
		Maximum	Minimum	Morning	Evening		
June							
23	4-10	37.9	23.6	78	39	28.8	2
24	11-17	34.6	23.2	88	54	27.1	3
25	18-24	32.4	23.1	79	52	10.9	3
26	25-01	33.0	23.0	79	49	0.0	0
July							
27	02-08	32.7	22.6	88	66	65.4	3
28	09-15	31.1	23.3	90	63	7.4	1
29	16-22	30.8	22.5	85	68	3.0	0
30	23-29	28.1	21.2	87	70	4.2	0
31	30-05	30.4	21.6	85	69	3.2	0
August							
32	06-12	29.3	21.7	89	73	11.6	3
33	13-19	30.4	22.3	87	61	11.3	1
34	20-26	30.7	21.3	86	58	41.5	3
35	27-02	28.4	20.9	90	70	15.4	2
September							
36	03-09	29.8	21.1	89	65	56.8	4
37	10-16	30.1	21.5	88	69	102.9	3
38	17-23	30.5	20.2	87	54	30.0	1
39	24-30	43.1	20.6	87	56	6.6	1
October							
40	01-07	29.5	21.0	89	66	159.0	3
41	08-14	30.4	19.3	81	38	0.0	0
42	15-21	29.3	15.6	83	41	6.2	1
43	22-28	29.0	19.9	90	65	203.8	3
44	29-04	29.1	13.7	84	32	0.0	0

VITA

9. VITA

GAJANAN DHONDIRAM PATIL

A candidate for the degree

of

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