EFFECT OF POD MATURITY STAGE, DRYING CONDITIONS AND ANTHRACNOSE DISEASE ON QUALITY OF DRY CHILLI (*Capsicum annuum* L.)

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ABSTRACT

Deterioration of quality due to discolouration of pods is an important factor that determines the market price of dry chilli. The quality of dry chilli is determined by the high initial red colour after drying and ability to retain the colour during storage. Agronomic and climatic factors and post-harvest handling factors can influence the quality of dry chilli. Hence, the effect of stage of pod maturity, method of drying, variety and incidence of anthracnose disease on quality of dry chilli were investigated in a series of experiments during 1996-1998 at the Field Crops Research and Development Institute, Maha Illuppallama. Superior quality dry chilli was produced when fruits were harvested at full-red-maturity stage. Harvesting pods prior to this stage reduced the red colour of dry pods, but harvesting pods at near-red maturity stage (80% red-mature) is acceptable. Sun-drying of full-red-colour pods immediately after harvest or keeping them for 2 days prior to sun-drying in a ventilated room produced 100% red coloured dry chilli. Keeping fully red fruits for 2 days in a ventilated room before sun-drying produced brighter and glistening dry chillies. Green mature pods when dried produced completely discoloured (straw colour) pods. Discolouration of chilli pods also depended on the method of drying, variety, disease incidence and climatic factors at the time of harvesting and drying. Sun-drying significantly lowered the number of discoloured pods (14 - 27%) compared to drying under shade or in a ventilated room (40 - 45%). This can be further reduced (14 - 17%) when pods are dried by spreading them on a mat rather than on the soil. High relative humidity and low temperature not only resulted in a longer period taken for drying, but also increased discolouration. Anthracnose disease is a major cause of poor quality in chilli produced during the Maha season. Depending on the variety and level of anthracnose infection the discolouration was as high as 50-60% of the pods.

KEY WORDS: Chilli, Quality, Deterioration, Sun drying, Anthracnose.

INTRODUCTION

In Sri Lanka, powdered or coarsely ground dry chilli (*Capsicum annuum* L.) is used in many food preparations to add flavour and colour. Colour is hence considered one of the important quality characters of dry chilli. High initial red colour as well as the retention of red colour over a longer period are important sensory quality characteristics. Farmers get very low prices for their produce due to poor sensory quality resulting from discoloured pods. Currently, discolouration during processing and colour change during storage, known as whitening of pods, have become important issues in dry chilli production. Colour change in powdered dry chilli has been found to be due to autoxidation (Carnevale *et al.*, 1980; Chen and Gutmanis, 1968), moisture content (Arya *et al.*, 1979; Chen and Gutmanis, 1968; Kanner *et al.*, 1977) and exposure to light (Carnevale *et al.*, 1979; and 1980; Lease and Lease, 1956a and 1956b; Ramakrishnan and Francis, 1979). However, investigations on the causes of colour change in dry pods are limited. Isidoro *et al.* (1990) reported that pods that were withered on or off the plant lost redness at a rate of about one-half of that for refrigerated powder during 84 days of storage.

In Sri Lanka, the average annual chilli production on a dry chilli basis ranges from 18,000 - 28,000 t and of this about 84% is consumed as dry chilli. Chilli pods are harvested by hand picking. Mostly, pods at different maturity stages are harvested and dried together without any sorting or grading. No much attention is paid to the quality of dried pods during drying. At times pods are dried on the roadside or on the soil surface without using any cover underneath. Therefore, it is important to investigate the pre-and post-harvest factors that influence the colour of dry chilli pods. The objective of this study was to investigate the effect of stage of harvesting, method of drying, variety and disease incidence on quality (colour) of dry chilli.

MATERIALS AND METHODS

Effect of stage of harvesting and curing

This experiment was conducted during the Yala season (1996) as it is easy to dry chilli during dry weather conditions and to control other factors that influence discolouration. A chilli crop (Var. MI-2) was transplanted in April 1996 and pods were harvested at 3 maturity stages, i.e: a). at full-red-maturity stage (whole fruit is fully red and no withering or wrinkling), b). near red maturity stage (80% of the surface area of the pod is red), and c). green mature pods. All pods were sun dried using two different methods. In the first method, pods were sun dried immediately after harvest and in the other, drying started only after keeping the pods for 2 days spread in a ventilated room. The ambient temperature and relative humidity during the day time were 30-34 °C and 81- 85%, respectively. Sun drying of all pods was carried by spreading on aluminium trays. Each treatment had 100 fruits and was replicated three times. After drying, fruits were graded into different colour groups using the Royal Horticultural Society (RHS) colour chart and the percentage fruits in each colour group was calculated. The experiment was repeated in Yala 1997.

Effect of drying method and variety

This study was conducted during Maha season 96/97 using three varieties of chilli, namely MI-2, KA-2 and Arunalu. Varieties were planted in an area of 86 m^2 each, and managed as recommended by the Department of Agriculture (DOA). Six harvests were collected during the period from January to March, 1997. The number of fruits at the first harvest was not sufficient to carry out the experiment and hence the study was confined to second to sixth harvests. At each harvest, fruits were sorted-out and only fully red-ripe fruits without any physical damage or disease symptoms were used. These fruits were spread and kept for 2 days in a ventilated room having a temperature range of 30-34°C during day time and RH 81-85%. Thereafter, pods were dried using the following 6 methods: 1. Sun-drying on bare soil, 2. Sun-drying on gunny (jute) bags, 3. Sun-drying on galvanized trays, 4. Shade-drying on gunny bags, 5. Drying inside a ventilated room on a gunny bag, 6. Oven drying at 35°C. Each treatment had 200 fruits and was replicated 3 times. At the end of drying, number of days taken for drying and the number of discoloured pods were recorded. Also air temperature, RH and rainfall during the drying period were recorded.

Effect of anthracnose disease

Effect of anthracnose disease on fruit quality deterioration was investigated for three consecutive seasons, namely Maha 96/97, Yala 97 and Maha 97/98. In these studies, 3 varieties, KA-2, MI-2 and Arunalu were planted in the field and managed with and without fungicide application to control the

anthracnose disease. Treatments were replicated 3 times. Plants used in the experiment carried out during Maha 96/97 season were transplanted in October 1996 while the date of planting for the Maha 97/98 trial had to be delayed until early November 97, which is 27 days later than in the previous Maha season. The trial in Yala 1997 was planted in June 1997. Fertilizer application, weeding and insect control were done according to the recommendations of the Department of Agriculture for all plots. Recommended chemicals for controlling anthracnose disease (Topsin and Daconil) were sprayed alternately at two - week intervals with the fungicide treatment proceeding from initial flowering stage to the end of final harvest. Topsin was sprayed at the concentration of 5.5 g/10 l of water while Daconil was applied at 32 g/16 l of water. Unsprayed (control) plots were kept free of fungicide applications. At each harvest, 200 pods were drawn randomly from each plot in each replicate and both good pods as well as the pods infected with anthracnose were counted. Degree of disease severity varied among pods. Some fruits had big leisons with blackish fruiting bodies of fungi whereas in others only initial symptoms of "pin-marks" were observed. All these fruits were counted as infected. Both lots (infected and uninfected) from a single plot were sundried in galvanized trays. After drying, the total number of discoloured fruits, and the number of fruits discoloured due to anthracnose were statistically analysed. Data on rainfall, relative humidity, maximum and minimum air temperature and sunshine hours during the experimental periods were collected. The mean values of all weather data collected 2 weeks prior to each harvesting and percentage discolouration were analysed to find out whether they are correlated to each other.

RESULTS AND DISCUSSION

Effect of stage of harvesting and curing

Number of fruits observed in different colour groups in each treatment in the experiments conducted in Yala 1996 and Yala 1997 is presented in Table 1. Stage of harvesting and method of curing had a significant effect on the colour of dry chilli (Fig. 1). Sun-drying of pods harvested at full-red colour stage irrespective of their method of curing, i.e. Sun-drying immediately after harvest or after keeping them for 2 days in a ventilated room, produced 100% red dry chillies in both seasons. Although there was no difference in the colour of dried pods in the two treatments, keeping fully red pods for 2 days indoors produced brighter and more glistening dry chilli pods (RHS 45B) over the pods that were dried immediately after harvest (RHS 45C).

When fresh fruits were harvested at 80% red maturity stage the distribution of red colour was more towards the tip of the fruit (80% of the area) and the area towards the stalk (20%) was green. When fruits were dried immediately after harvest, the red area turned into orange-red colour (RHS 34B) while the

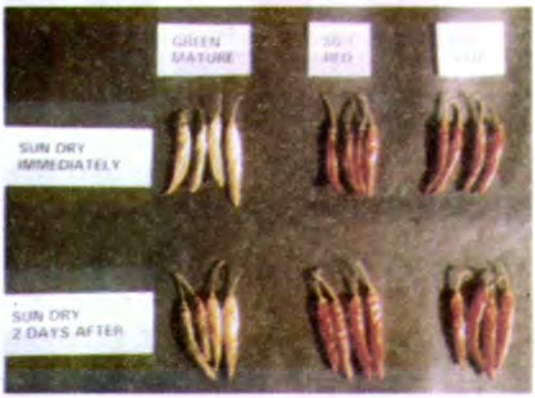

Fig. 1. Effect of stage of harvesting and curing on discolouration of dry chilli.

Table 1. Effect of stage of harvesting and curing on colour of dry chilli, variety MI-2 in Yala 1996 and 1997.

Method of drying	Stage of harvest (Maturity)	Percentage of fruits in colour groups									
		Gray yellow (*RHS 161B)		Gray orange (RHS 170B)		Orange red (RHS 34B)		Red group (RHS 45C)		(RHS 45 B)	
		Season									
		1996	1997	1996	1997	1996	1997	1996	1997	1996	1997
Sun drying immediately after harvest	Green	100	100	0	0	0	0	0	0	0	0
	80% red	0	0	0	0	100	100	0	0	0	0
	100% red	0	0	0	0	0	0	100	100	0	0
Sun drying 2 days after harvest	Green	91	93	9	7	0	0	0	0	0	0
	80% red	0	0	0	0	0	0	100	100	0	0
	100% red	0	0	0	0	0	0	0	0	100	100

* 'Based on the Royal Horticultural Society colour chart, London, Flower Council of Holland.

Table 2. Effect of the method of drying on discolouration of chilli pods of varieties MI-2, KA-2 and Arunalu harvested during the Maha 1996/97 season.

Method of drying	Mean number of discoloured pods per 200 pods
Direct sun drying on gunny bags	27 (14)*
Direct sun drying on galvanized tray	33 (17)
Direct sun drying on soil	53 (27)
Under a shade on gunny bags	79 (40)
Inside room on gunny bags	91 (45)
Oven drying at 35°C	93 (47)
LSD(0.05)	17
CV(%)	21

* Percentage values are given in the parentheses.

Table 3. Effect of variety on discolouration of chilli pods harvested during the Maha 1996/97 season.

Variety	Number of discoloured pods per 200 pods
MI-2	42 (21)*
Arunalu	53 (26)
KA-2	94 (47)
LSD (0.05)	12
CV(%)	21

* Percentage values are given in the parentheses.

green area turned to yellow-greenish colour (RHS 147B) resulting in 100% orange red dry chillies with greyish patches at the base of the fruit. However when 80% red-mature fruits were kept inside a ventilated room for 2 days, the whole fruit turned to a colour similar to the red ripe stage and this resulted in 100% red coloured fruits. However, when these pods were dried they were less glistening and brighter compared to the fully red fruits dried after keeping for 2 days indoors.

It has been reported that red colour in chilli is due to the mixture of carotenoids present in the fruits (Garcia, 1951 and Philip *et al.*, 1971). Keeping pods for two days in a ventilated room may have helped pods to synthesise more carotenoids both on the 80% red mature fruits as well as in full red mature pods. However, red mature pods will contain relatively more carotenoids than 80% red mature pods and that may be the reason for the glistening appearance of these pods after drying.

Effect of drying method and variety

Method of drying, variety and time of harvest (picks) showed significant effects on the colour of dried pods (Tables 2, 3 and 4). Interactions were not significant. Sun-drying took less days (4 days) for drying and gave a significantly lower percentage of discoloured pods (14 - 27%) compared to drying pods under shade (40%), inside a room (45%) and in an oven at 35°C (47%) (Table 2). However, of the three sun-drying methods tested, fruits dried on soil had a significantly higher number of discoloured pods (27%) compared to drying on gunny bags (14%) and on galvanized trays (17%). When discoloured pods were cut open,

most of them had fungal mycelia of *Aspergillus* and *Alternaria* inside. The fruits dried under shade and inside a room had more fungal mycelial growth. The longer period taken for drying under shade (9-11 days) and inside a room (14 days) would have provided more time for the fungi to colonize the fruits. The percentage of discolouration of pods during Maha (96/97) season was generally higher compared to the previous experiment, which was conducted during Yala 96. This could be due to the wet climatic conditions, low sunlight and high RH that prevailed during the Maha season. Therefore, further investigations on the effect of season on dry chilli production are required.

The variety is also an important factor that determines the colour of dried pods. Of the three varieties tested, MI-2 produced the lowest number of discoloured pods (21%) while KA-2 had the highest number of discoloured pods (47%) (Table 3). There was no significant difference between the number of discoloured pods in MI-2 (21%) and Arunalu (26%). Fruit pericarp thickness of the chilli variety KA-2 is higher (1.3 mm) than of the other two (1 mm). Higher pericarp thickness would have contributed to slow and incomplete drying of pods in KA-2, which can promote fungal growth resulting in colour degradation.

Different harvests showed significant differences in the number of discoloured pods (Table 4). Second and third harvests produced significantly higher number of discoloured pods but the percentage was low in fourth to sixth harvests. The reasons for differences in pod discolouration at different harvesting periods were mainly due to the climatic factors that prevailed during a particular time of harvesting and drying. Harvesting and drying period from second and sixth picks occurred during late January 1997 to early April 1997 and the temperature, humidity (morning and afternoon) and rainfall were different at each harvest/drying period (Table 5). During the second and third harvests, the average air temperature was around 32°C and the humidity was in the range of 78-88% in the morning and 57-75% in the afternoon with no rains. Under these climatic conditions, pods picked in the second and third harvests took a longer time to dry (6 days) and had the highest number of discoloured pods (Table 4). Low temperature and high humidity that prevailed during this period would have resulted in slow drying and enhanced fungal growth leading to discolouration of pods. The temperature during the drying period of fourth, fifth and sixth harvests was 35 - 36°C with the relative humidity ranging from 78-83% in the morning and 42-70% in the afternoon. On these three occasions, pods took a shorter period for drying (3-4 days for sun drying) resulting less discoloured pods (20-24%). This shows that the relative humidity, temperature and their interactions during the drying period have a great influence on the quality of chilli. When chilli pods are dried at higher RH (> 83%) and air temperature is low (<32°C), the possibility of getting a higher percentage of discoloured pods is high. Results also reveal that during the Maha season, the possibility of producing quality dry chilli especially for long-term storage is low compared to the Yala season.

Effect of anthracnose disease on the quality of dry chilli

All pods that were infected with anthracnose had discoloured patches on the fruit surface after drying (Fig. 2). The size of the patch varied with the degree of infection. Among infected pods, those which showed severe symptoms with black fruiting bodies of fungi had large gray patches while fruits with minor infection had straw coloured small or enlarged patches.

Table 4. Effect of harvest on discolouration of chilli pods of varieties MI-2, KA-2, Arunalu during the Maha 1996/97 season.

Harvest	Number of discoloured pods per 200 pods
2nd pick	81 (41)*
3rd pick	101 (50)
4th pick	41 (21)
5th pick	47 (24)
6th pick	40 (20)
LSD(0.05)	15
CV(%)	21

* Percentage values are given in the parentheses

Table 5. Number of days taken for drying using different sun-drying methods for different harvests and climatic conditions during Maha 1996/97.

Method of drying	No.of days				
	2nd pick	3rd pick	4th pick	5th pick	6th pick
Sun drying on gunny bags	6	6	4	3	3
Sun drying on galvanized trays	6	6	4	3	3
Sun drying on soil surface	6	6	4	3	3
Average air temperature (°C)	31.5	32.3	34.7	35.3	36.3
Relative humidity					
- Average	83.0	85.0	81.5	79.3	79.0
- Morning (8.30 a.m.)	78-87	82-88	78-83	77-82	78-80
- Afternoon (5.30 p.m.)	69-75	57-67	42-55	43-59	60-70

Fig. 2. Dry pods with different degrees of infection by anthracnose.

The percentage discolouration due to anthracnose in different treatments varied with the season, harvesting time (picks), variety and fungicide spraying. The percentage of discolouration in chilli pods was significantly higher in the crop that was planted during the 96/97 Maha season than in the Yala crop (Fig. 3). However, climatic conditions at harvesting time in a particular season had a significant effect on the incidence of anthracnose disease and thereby the percent discolouration of pods. Harvesting period of the crop planted during Maha 96/97 was mid-January to late March (Fig. 3a) while it was mid- February to mid- April for the crop planted on Maha 97/98 (Fig. 3c). During Maha 96/97, the highest number of discoloured pods (16-53%) due to anthracnose was in pods harvested in January and it gradually decreased towards February and March (5-11%) (Fig. 3a). The low percentage of discolouration during February and March was also seen for the crop planted in Maha 97/98 (Fig. 3c). Because of the delay in crop establishment in Maha 97/98, harvesting had to be extended until the end of April. Even though a slightly higher percentage of discolouration occurred in April with the beginning of Yala rains still the percentage discolouration was quite low (6%) (Fig. 3c). The crop established in Yala 97 was harvested from early September to early October 1997 and during this period it was dry and air temperature was high. The percentage discolouration due to anthracnose for the varieties during this period was very low and varied from 0.5 - 3% (Fig. 3b).

The difference in anthracnose infection at different harvesting periods of the season was mainly due to the climatic conditions that prevailed at a particular harvesting time (Table 6). The relative humidity during the two weeks period preceding harvesting was directly correlated with the percentage discolouration ($r = 0.86$). The maximum temperature during harvesting was negatively correlated ($r = - 0.93$) with discolouration whereas other weather parameters had very low correlation values. It is reported that the optimum condition for the development of anthracnose disease is 28°– 30°C and RH over 90% (Chung and Lee, 1986). During January, the relative humidity was over 84% and the maximum temperature was around 30-31°C with mist during early morning hours (Table 6). These climate conditions are more

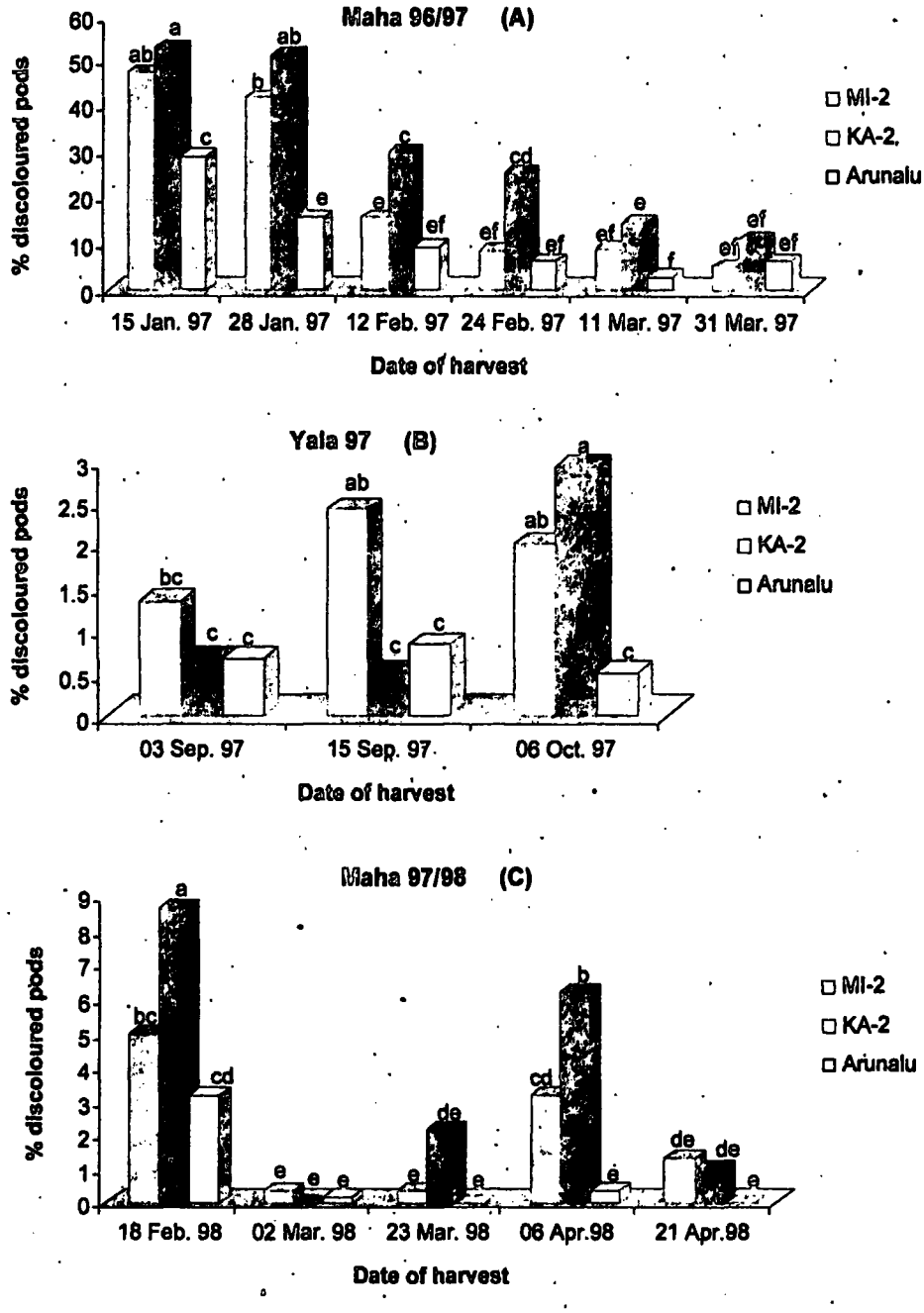

Fig. 3. **Percent discoloured pods in three varieties of chilli at different harvests during three seasons, Maha 96/97 (A), Yala 97 (B) and Maha 97/98 (C). Columns with the same letter are not significantly different at $P < 0.05$ as determined by Duncan's Multiple Range Test.**

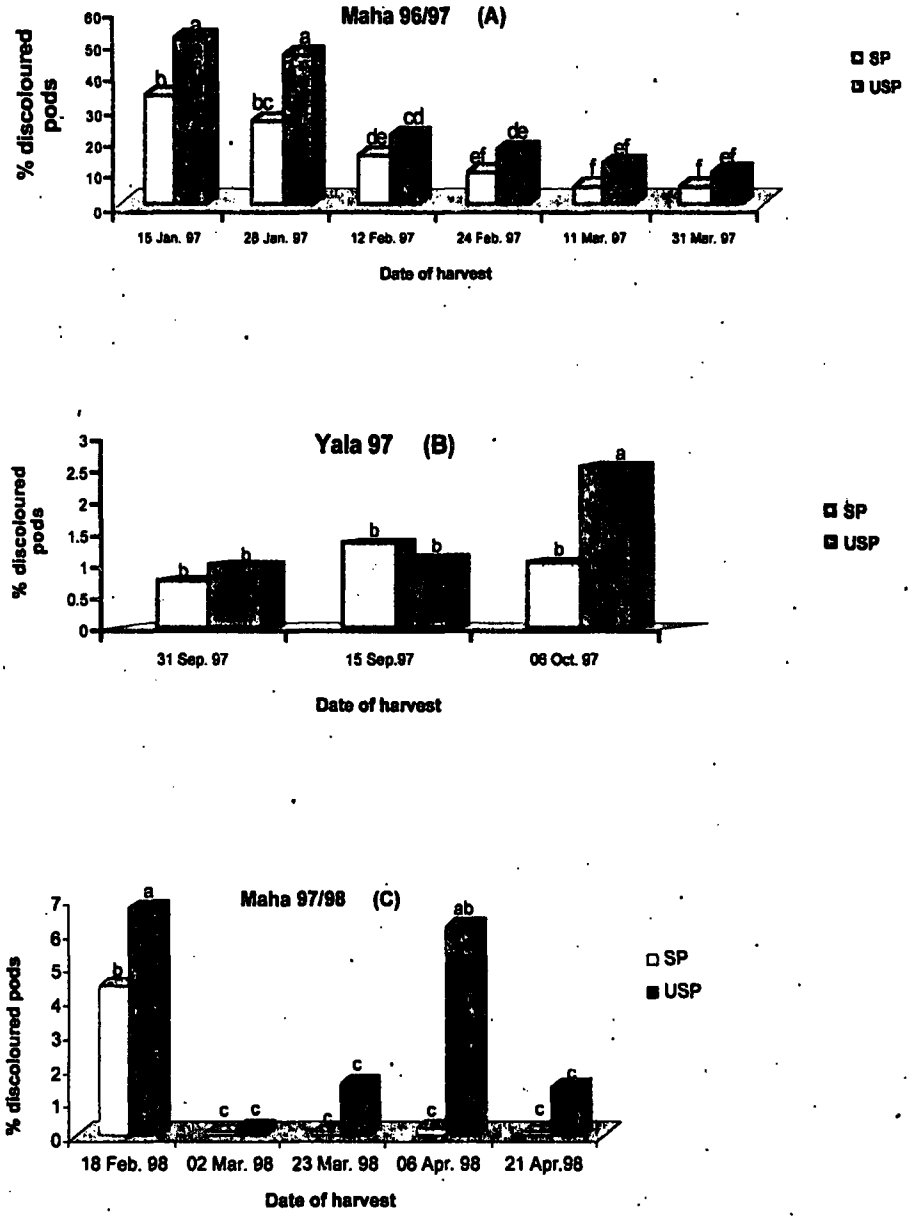

Fig. 4. **Percent discoloured pods at different harvests under sprayed (SP) and unsprayed (USP) conditions during three seasons, Maha 96/97(A), Yala 97(B) and Maha 97/98 (C). Columns with the same letter are not significantly different at $P < 0.05$ as determined by Duncan's Multiple Range Test.**

favourable for development of anthracnose disease which will result in more discoloured pods. Low RH (77 - 81%) and the high temperature (33 – 36°C) that prevailed during February - April and in September did not favour the development of disease and thereby gave a low percentage of discoloured pods.

The incidence of anthracnose disease varied with the variety. The variety Arunalu had the least incidence of anthracnose followed by MI-2 during the Maha season (Fig. 3a). Variety, KA-2 had the highest disease incidence. However, during the Yala season, the climatic conditions were dry during the harvesting period and hence the development of the disease in variety KA-2 was also very low (Fig. 3b). As a result, the discolouration of pods in KA-2 was low and similar to Arunalu. Unsprayed plots had a higher percentage of discolouration over the sprayed treatments at each harvest during the Maha season (Fig. 4a) while there was no effect of spraying on the crop planted during the Yala season up to September (Fig. 4b). The effect of fungicide spraying was more prominent in KA-2 than in the other two varieties (Table 7). Arunalu possess a moderate level of resistance to anthracnose and this has attributed to the low disease incidence and thereby low number of discoloured pods.

CONCLUSIONS

The stage of harvesting, variety, curing and drying method, and the incidence of anthracnose in pods affect the percentage of discolouration of chilli fruits. Harvesting fruits at fully-red ripe stage is important to produce red coloured dry chillies. Action should be taken as much as possible to harvest red mature stage pods. However, under actual field conditions harvesting only the full-red mature stage pods is difficult and costly. A certain percentage of pods with partial maturity will be harvested by the pickers and hence separation of pods with less than 80% red-maturity is important prior to curing. Green fruits when dried produce a gray-yellow-colour or gray colour with yellow-green patches and presence of these discoloured pods reduces the quality. Discolouration of chilli pods also depends on the method of drying, variety and the climatic factors that prevail during the period of harvesting and drying. Keeping harvested pods under shade for at least 2 days will not only improve the red-colour of near full maturity pods but also improve the quality of full-red-mature pods by increasing their lustre / brightness. Sun drying will give a higher percentage of good quality dry chilli compared to drying in the shade or inside a ventilated room. Sun drying on gunny-mats is better than drying on soil or galvanized trays. Of the three recommended varieties, MI-2 and Arunalu produces better quality pods. When chilli pods are dried at higher RH (>80%) and moderate air temperatures (<32°C) the possibility of getting a higher percentage of discoloured pods is high.

The amount of anthracnose infection is closely related to rainfall, RH and air temperature. During periods of high rainfall and moderate temperatures the incidence of anthracnose is high and thus discolouration of pods is also high. Of the recommended varieties, Arunalu has a high level of tolerance to anthracnose and produces less discoloured pods. Using the correct variety and avoiding weather conditions that favour development of anthracnose could minimize pod discolouration in dry chilli due to anthracnose. Use of fungicide will help to reduce the disease and thereby reduce discolouration but the two recommended fungicides (Topsin and Daconil) used (at 2 weeks intervals) were not very effective in controlling the disease.

Table 6. Variation in maximum temperature and relative humidity during harvesting period of two Maha seasons (96/97 and 97/98) and one Yala season (97) at, Maha Illuppallama.

Harvesting period	1996/97				1998			
	Maximum Temperature °C		Relative Humidity (RH)		Maximum Temperature °C		Relative Humidity (RH)	
	Range	Mean (SD±)	Range	Mean (SD ±)	Range	Mean (SD±)	Range	Mean (SD ±)
18 Dec - 31 Dec	26 - 30	29±1.02	83 - 96	90±3.99	–	–	–	–
01 Jan - 14 Jan	28 - 31	30±0.75	81 - 95	88±4.70	–	–	–	–
15 Jan - 28 Jan	30 - 33	31±0.80	77 - 93	84±3.79	28 - 33	31±1.19	75 - 90	83±4.28
29 Jan - 11 Feb	30 - 33	32±0.70	68 - 91	88±6.26	31 - 33	32±0.59	71 - 90	83±4.64
12 Feb - 25 Feb	31 - 34	33±1.21	73 - 90	81±4.56	31 - 35	33±1.24	74 - 93	83±4.39
26 Feb - 11 Mar	27 - 35	33±1.79	62 - 87	77±7.42	33 - 36	35±0.88	74 - 84	80±3.02
12 Mar – 25 Mar	35 - 37	36±0.52	67 - 86	80±5.28	33 - 37	35±1.11	71 - 87	78±4.38
26 Mar – 08 Apr	32 - 36	35±1.06	70 - 90	81±5.61	35 - 37	36±0.60	72 - 80	77±2.35
09 Apr - 22 Apr	33 - 37	35±1.14	75 - 93	81±4.98	35 - 37	36±0.53	71 - 85	79±3.90
23 Apr - 06 May	32 - 35	33±0.60	76 - 90	83±4.46	32 - 37	34±1.72	76 - 86	81±2.90
07 Aug – 19 Aug	33 - 34	34±0.50	71 - 81	75±3.25	–	–	–	–
20 Aug – 02 Sep	32 - 35	33±2.79	70 - 84	76±3.85	–	–	–	–
03 Sep - 16 Sep	31 - 36	34±1.39	67 - 86	77±5.67	–	–	–	–
17 Sep - 30 Sep	28 - 33	31±1.36	74 - 93	83±5.68	–	–	–	–
01 Oct - 14 Oct	30 - 34	32±0.86	78 - 90	84±3.31	–	–	–	–

Table 7. Percent discoloured pods in three varieties of chilli under sprayed and unsprayed conditions during three seasons at FCRDI, Maha Illuppallama.

Variety	Discoloured pods (%)					
	Maha 96/97		Yala 97		Maha 97/98	
	SP	USP	SP	USP	SP	USP
MI-2	18	24	2	2	1	3
	(23)*	(28)*	(1)	(2)	(4)	(8)
KS-2	18	44	1	2	1	6
	(24)	(41)	(1)	(1)	(2)	(12)
Arunalu	12	12	1	1	1	1
	(19)	(18)	(1)	(1)	(3)	(2)
Mean	16	27	1	2	1	3
	(22)	(29)	(1)	(1)	(3)	(8)
LSD(0.05) for spraying x variety	5.6		NS		1	
CV (%)	20		19		20	

SP - Sprayed, USP - Unsprayed

* Arc sine transformed values are given in the parentheses.

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