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Soil Thermal Regimes Under Two Rice Genotypes and its Effect on Growth and Yield

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ABSTRACT

Studies on cool temperature injury on paddy rice leading to poor fertilization of florets and low grain set have established the detrimental effect of low temperature. But hardly any study has been made on the effect of soil thermal regimes on growth and development of paddy under tropical conditons. Thus an experiment was conducted at Auxiliary Evapotranspiration Station, Raipur to study the effect of soil thermal regimes on growth and development of two genotypes *viz.*, Shyamala and Mahamaya. The study revealed that the mean weekly soil temperature ranged between 21.9 to 30.3 °C in 1997 and 19.3 to 30.2 °C in 1999 under Shyamala and 22.5 to 30.1 °C in 1997 and 19.0 to 30.0 °C in 1999 under Mahamaya genotype at 5 and 20 cm soil depths during the growing seasons. Considerable increase in soil temperature at 5 cm depth at 1400 hours was observed under Shyamala compared to that of Mahamaya. The difference in mean weekly soil temperature between Shyamala and Mahamaya genotypes at 5 and 20 cm soil depths were positive in general and ranged between 0.1 to 1.5 °C at active vegetative, flowering, grain formation and maturity stages, except for few weeks when values were found negative. This was due to higher LAI (6-11 in Mahamaya and 5-9 in Shyamala), plant height, more number of tillers and more number of leaves under Mahamaya compared to that of Shyamala. The higher soil thermal regimes under Shyamala has resulted in higher consumptive use of water and significant reduction in yield of Shyamala compared to that of Mahamaya during 1997 and 1999. The yield of Shyamala and Mahamaya genotypes ranged between 21 to 24 and 24 to 80 q/ha respectively. This indicates that Mahamaya genotype is superior and may be recommended to the farming community.

Introduction

The importance of studying evapotranspiration (ET) from crop surface being a primary function in energy exchange and the water balance in crop communities, needs no justification. Difference in the distribution of source and sink of water, besides the soil conditions, decides the growth of crop in a region. However, the rice varieties have adopted themselves to diversified soil, water and climatic conditions. It's yield widely fluctuates due to variations in the rainfall. Evaporative demand and thermal regimes of a region are two equally important factors that largely affect dry matter production and yield of rice. So the study of ET and thermal regimes of a crop in a particular region for its growth, development and yield is important. Selection of the genotypes of rice suitable for an agroclimatic region based on optimum environmental condition as modified by their own growth characteristics also play an equally important role. Thus an attempt has been made to study the growth characteristics of two rice genotypes *viz.*, Shyamala and Mahamaya in relation to canopy temperatures and soil thermal regimes at Raipur situated in the sub humid torpic.

Materials and Methods

A collaborative experiment was conducted at the research farm of Indira Gandhi Agricultural University, Raipur, Madhya Pradesh to study growth characteristics, evapotranspiration pattern and thermal regimes under two rice genotypes. The experiment was conducted during kharif season of 1997 and 1999. Two rice varieties *viz.*, Shyamala and Mahamaya were transplanted on 6th August 1997 and 20th August 1999, respectively in one each of the two lysimetric tanks and surrounding plots. The soil thermometers at 5 and 20 cm soil depths and two thermometers at 10 and 50 cm heights in the crop canopy were installed in the ET tank. ET at 0700 hrs LMT and soil and

canopy temperatures at 0700 and 1400 hrs LMT from both the rice genotypes were recorded daily. Other meteorological data *viz.*, evaporation, maximum and minimum temperatures, relative humidity, rainfall etc. recorded daily at 0700 and 1400 hrs LMT were obtained from the near by agrometeorological observatory at Raipur. The recording of weekly phenological observations from 10 selected plants were made throughout the growth period from each of the lysimetric tanks and also from each of the four adjacent plots of size 3 x 3m. Grain yield and dry biomass are presented in Table 1.

Results and Discussions

At 10 cm height, weekly canopy temperature at 0700 hrs ranged between 19.7 to 26.9°C in 1997 and 14.0 to 27.5°C in 1999 under Mahamaya genotype (Fig.1a). At 50 cm height, weekly canopy temperature at 0700 hrs ranged between 21.6 to 27.3°C in 1997 and 15.1 to 27.4°C in 1999 under Mahamaya genotype (Fig.1b). During early vegetative to active vegetative stages canopy temperature was more or less constant. Maxima (26.9°C) was attained at boot leaf stage. After attaining panicle initiation stage, weekly canopy temperature decreased slowly by 1 to 2°C and then rapidly upto maturity stage. On the other hand, in the year 1999, canopy temperature decreased rapidly by 5°C at flowering stage. It increased slowly upto harvesting stage under both the genotypes Shyamala and Mahamaya (Fig. 1).

At 1400 hrs, weekly canopy temperature ranged between 26.8 to 34.5°C in 1997 and 27.9 to 35.5°C in 1999 under Shyamala genotype and 21.7 to 33.2°C in 1997 and 27.2 to 34.1°C in 1999 under Mahamaya genotype at 10 cm height (Fig.1c). It may be seen from Fig. 1c that in the year 1997, weekly canopy temperature at 1400 hrs at 10 cm height initially decreased upto active vegetative stage and then increased slowly upto panicle initiation stage with a little drop at boot leaf stage. In the year 1999, decrease in weekly canopy temperature at 1400 hrs at 10 cm height was seen at early vegetative stage, but it increased upto panicle initiation state. It dropped rapidly upto flowering stage at 10 cm height and then increased slightly upto maturity stage by 2°C. In both the years Shyamala genotype was having higher canopy temperature regime than that Mahamaya genotype at 1400 hrs at 10 cm height.

Similar trend was observed at 50 cm height (Fig1d). It may be seen that at 1400 hrs at 50 cm height weekly canopy temperature ranged between 22.9 to 33.4°C in 1997 and 27.9 to 40.7°C in 1999 under Shyamala genotype and 22.2 to 32.3°C in 1997 and 30.0 to 39.5°C in 1999 under Mahamaya genotype. Fig1(e) shows that at 10 cm height mean canopy temperature (mean of 0700 and 1400 hrs) ranged between 21.9 to 30.7°C in 1997 and 23.8 to 30.5°C in 1999 under Shyamala genotype and 20.9 to 29.9°C in 1997 and 21.6 to 30.4°C in 1999 under Mahamaya genotype. At 50 cm height mean canopy temperature (mean of 0700 and 1400 hrs) ranged between 22.7 to 30.4°C in 1997 and 26.6 to 32.6°C in 1999 under Shyamala genotype and 21.2 to 29.7°C in 1997 and 25.8 to 31.8°C in 1999 under Mahamaya genotype (Fig.1f).

The difference in canopy temperature between Shyamala and Mahamaya genotypes were, in general, positive and ranged between 0.1-0.2 at active vegetative stage, 0.3-1.3 at boot leaf stage, 0.2-1.4 at panicle initiation stage, 0.2-0.9 at flowering, 0.0-0.6 at grain formation stage and 0.2-3.8 at harvesting stage except for few weeks between 44th to 48th when values were found negative.

At 5 cm soil depth weekly soil temperature at 0700 hrs ranged between 19.7 to 28.3°C in 1997 and 16.7 to 27.6°C in 1999 under Shyamala genotype and 21.1 to 28.5°C in 1997 and 16.8 to 26.9°C in 1999 under Mahamaya genotype (Fig. 2a). Similarly at 20 cm soil depth weekly soil temperature at 0700 hrs ranged between 22.4 to 28.6°C in 1997 and 19.2 to 28.5°C in 1999 under Shyamala genotype and 22.9 to 28.6°C in 1997 and 18.7 to 28.2°C in 1999 under Mahamaya genotype (Fig. 2b). With the advancement of crop growth stages height of plant, no. of green leaves and tillers increased gradually causing drop in soil temperature from early vegetative to flowering stages but after grain formation stage it decreased slowly by 1°C in the year 1997 whereas it decreased rapidly by 5°C in the year 1999 when maturity stage was attained (Fig. 2a and 2b).

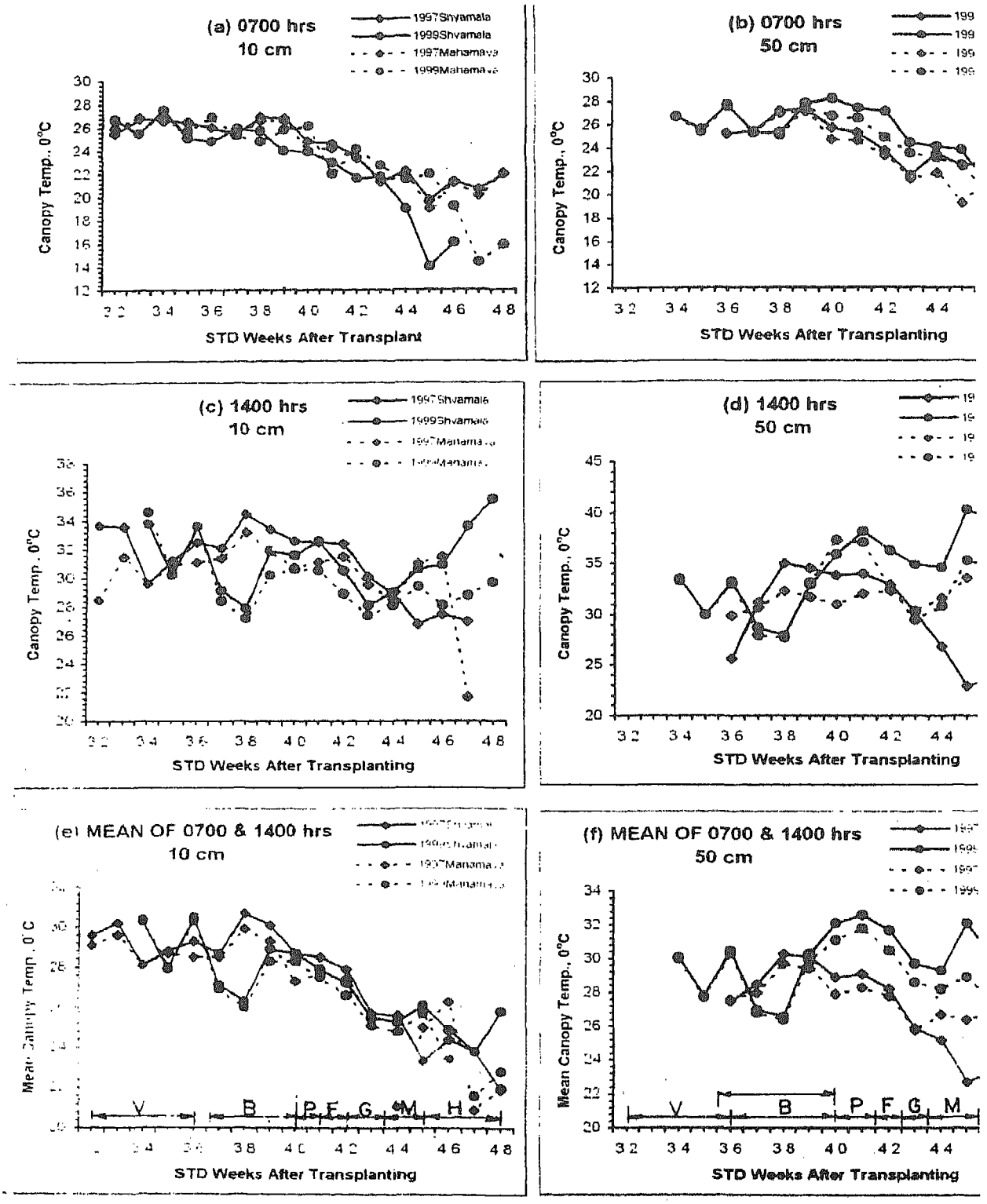

Fig. 1. (a, b, c and d) : Variation of canopy temperature at 0700 and 1400 hrs

(e and f) : Variation of mean (Mean of 0700 and 1400 hrs) canopy temperature at 10 and 50 cm heights

V : Vegetative; B : Boot leaf, P : Panicle, F : Flowering, G : Grain formation, M : Maturity, H : Harvest

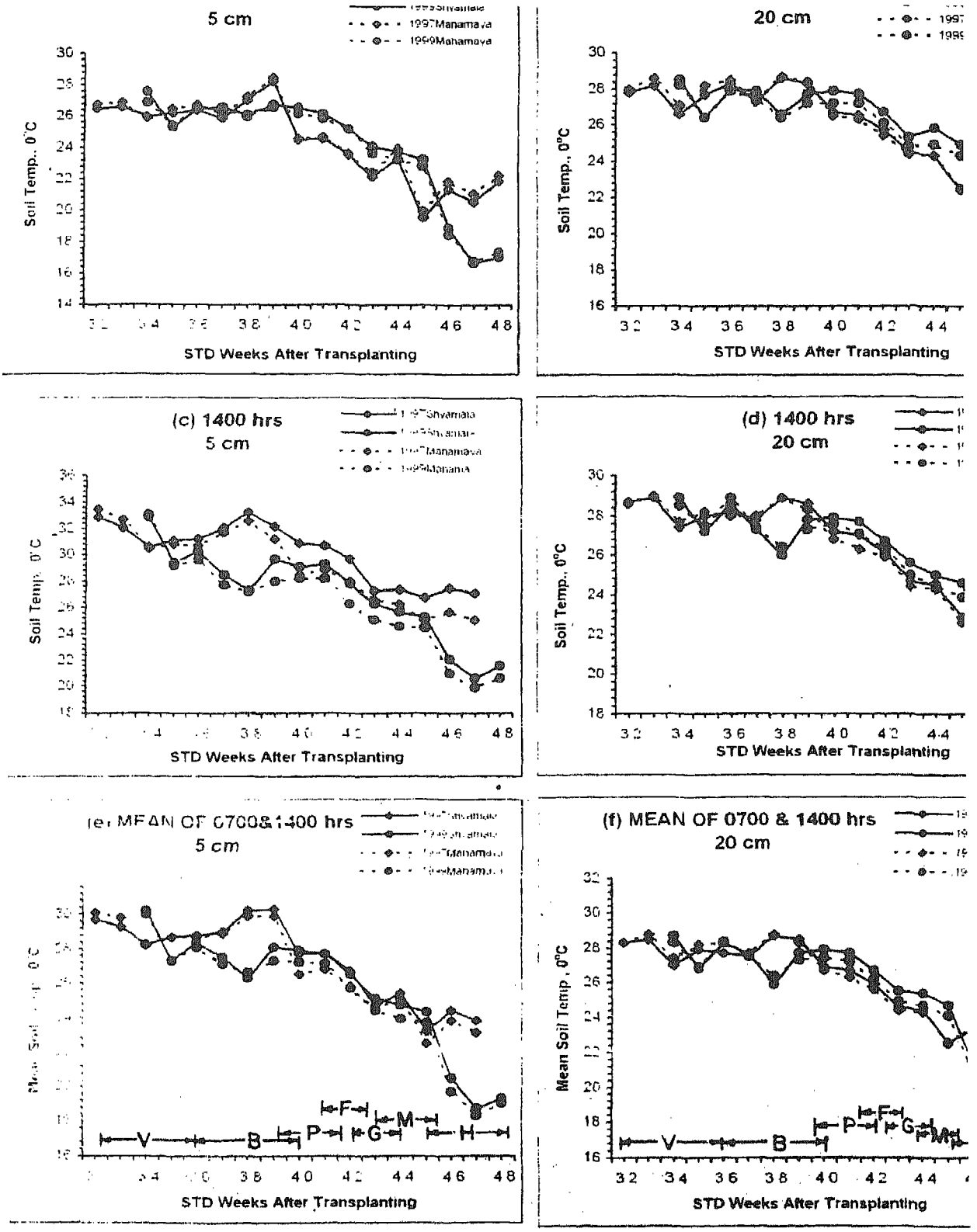

Fig. 2. (a, b, c and d) : Variation of soil temperature at 5 cm and 20 cm depth at 0700 and 1400 hrs

(e and f) : Variation of mean (Mean of 0700 and 1400 hrs) soil temperature atg 5 cm and 20 cm depths

V : Vegetative; B : Boot leaf, P : Panicle, F : Flowering, G : Grain formation, M : Maturity, H : Harvest

Decrease in soil temperature was more pronounced under Mahamaya genotype at 5 cm soil depth in the year 1999.

At 1400 hrs, weekly soil temperature ranged between 26.8 to 32.9°C in 1997 and 20.6 to 32.9°C in 1999 under Shyamala genotype at 5 cm soil depth (Fig.2c). Drop in soil temperature was observed from early vegetative to active vegetative stage followed by an increase with a peak at early boot leaf stage (33.3°C) in the year 1997 and at vegetative stage (32.9°C) in the year 1999 (Fig. 2c) at 5 cm soil depth at 1400 hrs. A gradual drop in soil temperature was seen thereafter till harvesting stage. It is interesting to note from the soil temperature graphs that the year 1997 and 1999 were distinctly separable from each other. It was considerably higher in the year 1997 compared to that in the year 1999. It may also be seen that Mahamaya genotype was having lower soil temperature than that of Shyamala genotype. Whereas at 20 cm soil depth in both the years with both the varieties there was not much difference in soil temperature. It dropped gradually from vegetative to harvesting stage, with a peak at 36th week after transplanting (Fig. 2d). At 1400 hrs at 20 cm soil depth weekly soil temperature ranged between 22.9 to 28.9°C in 1997 and 19.2 to 28.9°C in 1999 under Shyamala genotype and 22.6 to 29.0°C in 1997 and 19.2 to 28.9°C in 1999 under Mahamaya genotype. Decrease in soil temperature was more gradual in the year 1997 whereas in the year 1999, after attending grain formation stage it decreased rapidly by 5°C during maturity to harvesting stage (Fig. 2d).

Fig. 2e shows that at 5 cm soil depth mean soil temperature (mean of 0700 and 1400 hrs) ranged between 23.2 to 30.3°C in 1997 and 18.7 to 30.2°C in 1999 under Mahamaya genotype. Mean soil temperature at 5 cm soil depth decreased gradually upto vegetative stage then it increased slowly upto boot leaf stage showing a peak of 30.3°C in the year 1997. Thereafter, it decreased slowly upto harvesting stage. In the year 1999 it decreased slowly and peak temperature (28.1°C) was observed at late vegetative stage. Thereafterm it decreased gradually upto harvesting stage. Mean soil temperature at 20 cm soil depth remained more or less constant from early vegetative to grain formation stages. It dropped drastically at maturity stage (Fig. 2f). At 20 cm soil depth mean soil temperature (mean of 0700 and 1400 hrs) ranged between 22.6 to 28.7°C in 1997 and 19.2 to 28.7°C in 1999 under Shyamala genotype and 22.5 to 28.8°C in 1997 and 18.9 to 28.4°C in 1999 under Mahamaya genotype (Fig. 2f).

The difference in mean weekly soil temperature between Shyamala genotype and Mahamaya genotype at 5 cm and 20 cm soil depths were in general positive and ranged between 0.1-0.3 at vegetative stage, 0.1-0.6 at boot leaf and panicle initiation stages, 0.1 to 1.1 at flowering stage, 0.1-0.8 at grain formation stage and 0.1-1.9 at harvesting stage except for the weeks between 44th to 48th when values were found negative. This was due to higher LAI of Mahamaya (6-11) compared to that of Shyamala (5-9). Higher plant height, more no. of leaves and more no. of tillers under Mahamaya compared to that of Shyamala genotype were the causes of such variation in soil thermal regimes.

The rate of ET increased with successive growth stages attaining a peak during early reproductive stage. Hence booting, heading and flowering stages can be considered as critical stages as these exhibit peak period of water consumption (Maske *et al.*, 1990). It may be seen from (Fig. 3) that at the early vegetative stage (just after transplanting) the average total weekly ET was ranged between 20.8 to 45.6 mm/week under Shyamala and 18.5 to 46.3 mm/week under Mahamaya genotype in the year 1997. Whereas it was considerably lower in the year 1999 and ranged between 18.4 to 20.2 mm/week under Shyamala and 18.3 to 23.0 mm/week under Mahamaya genotype. ET rate then increased having peak (51.5 mm/week in Shyamala, 50.8 mm/week in Mahamaya in 1997 and 44.3 mm/week in Shyamala, 46.7 mm/week in Mahamaya in 1999) at boot leaf stage. Thereafter, the rate of ET started decreasing touching the lowest value at harvesting stage. ET rate was considerably higher at maturity stage (29.2 mm/week in Shyamala, 26.6 mm/week in Mahamaya in 1997 and 55.1 mm/week in Shyamala, 53.5 mm/week in Mahamaya in 1999). The peak values occurred during boot leaf to maturity stages which indicate the higher water

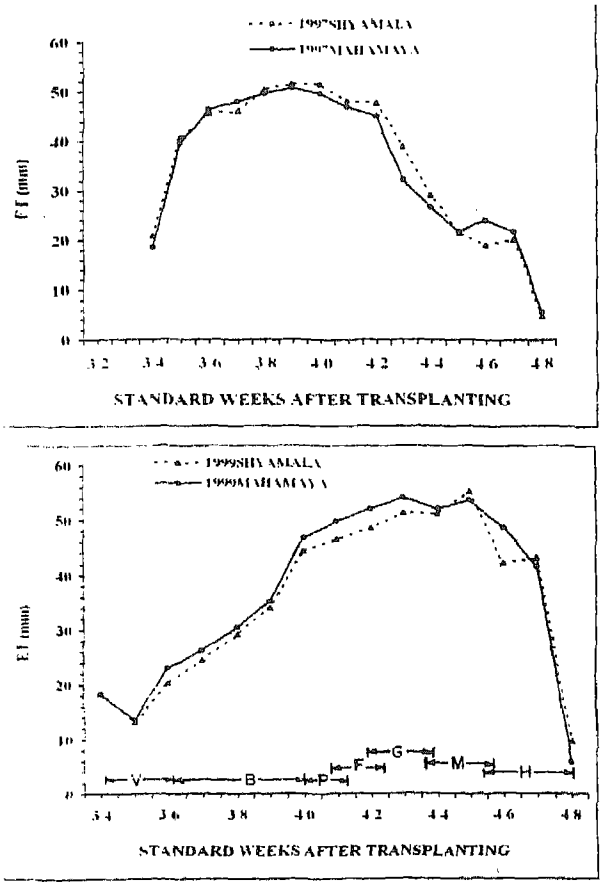

Fig. 3. Evapotranspiration of Shyamala and Mahamaya at different growth stages

V : Vegetative; B : Boot leaf, P : Panicle, F : Flowering, G : Grain formation, M : Maturity, H : Harvest

demand at these stages (Shrivastava *et al.*, 1997). The ET rate was higher in Shyamala genotype in the year 1997 due to higher thermal regimes whereas it was higher with Mahamaya genotype in the year 1999 due to higher LAI and growth which caused lower soil thermal regime due to trapping of most of the incoming solar radiation.

It may be seen from fig. 4 that during early vegetative growth stage i.e. from 1st week to 4th week after transplanting, average plant height was 20 and 25 cm in the year 1997 and 20 and 41 cm in the year 1999 under Shyamala and Mahamaya genotypes, respectively. Average maximum height ranged between 45 to 62 cm and 64 to 75 cm under Shyamala and Mahamaya genotypes, respectively, during active vegetative to maturity stages in the year 1997. Whereas in the year 1999, plant height was slightly lower and ranged between 20 to 40 cm and 50 to 75 cm under Shyamala and Mahamaya genotypes respectively during flowering to maturity stages. During early vegetative to flowering stages, favourable weather conditions (average weekly rainfall was 64 mm) helped growth of green leaves, panicles etc. For example, 22 to 33 and 31 to 51 green leaves were observed under Shyamala genotype and Mahamaya genotype, respectively, during early vegetative stage in the year 1997. During the same period 19 to 35 and 33 to 44 green leaves were observed under Shyamala and Mahamaya genotypes respectively, in the year 1999. After panicle initiation stage, decrease in no. of green leaves occurred slowly but continuously till harvesting. In the year 1997, both genotypes were having more or less the same no. of green leaves in early vegetative stage compared to that in the year 1999. In the year 1999, during active vegetative stage when Shyamala genotype was having 20 no. of green leaves per hill, Mahamaya genotype was having 33 no. of green leaves per hill. During active vegetative stage Shyamala had only 35 no. of green leaves per hill whereas Mahamaya genotype was having 44 no. of leaves per hill showing much more vegetative growth and LAI there by trapping of more radiation by the canopy of Mahamaya genotype and less penetration of radiation below the canopy. This has caused much less soil heat flux and a considerable difference in the soil temperature both at 5 and 20 cm soil depths between the Shyamala and Mahamaya genotypes.

Similar trend was observed with number of panicles. In the year 1997, the no. of panicles were more or less same both under Shyamala and Mahamaya genotypes but in the year 1999 there were large difference in no. of panicles. In the year 1997, both the genotypes were having 2-6 no. of panicles during flowering to harvesting stages, whereas in the year 1999, Shyamala genotype was having 1-4 panicles at flowering stage and Mahamaya genotype was having 4-8 no. of panicles. At maturity stage, Shyamala genotype was having a mean of 4.2 no. of panicles whereas Mahamaya genotype had an average 6.2 no. of panicles.

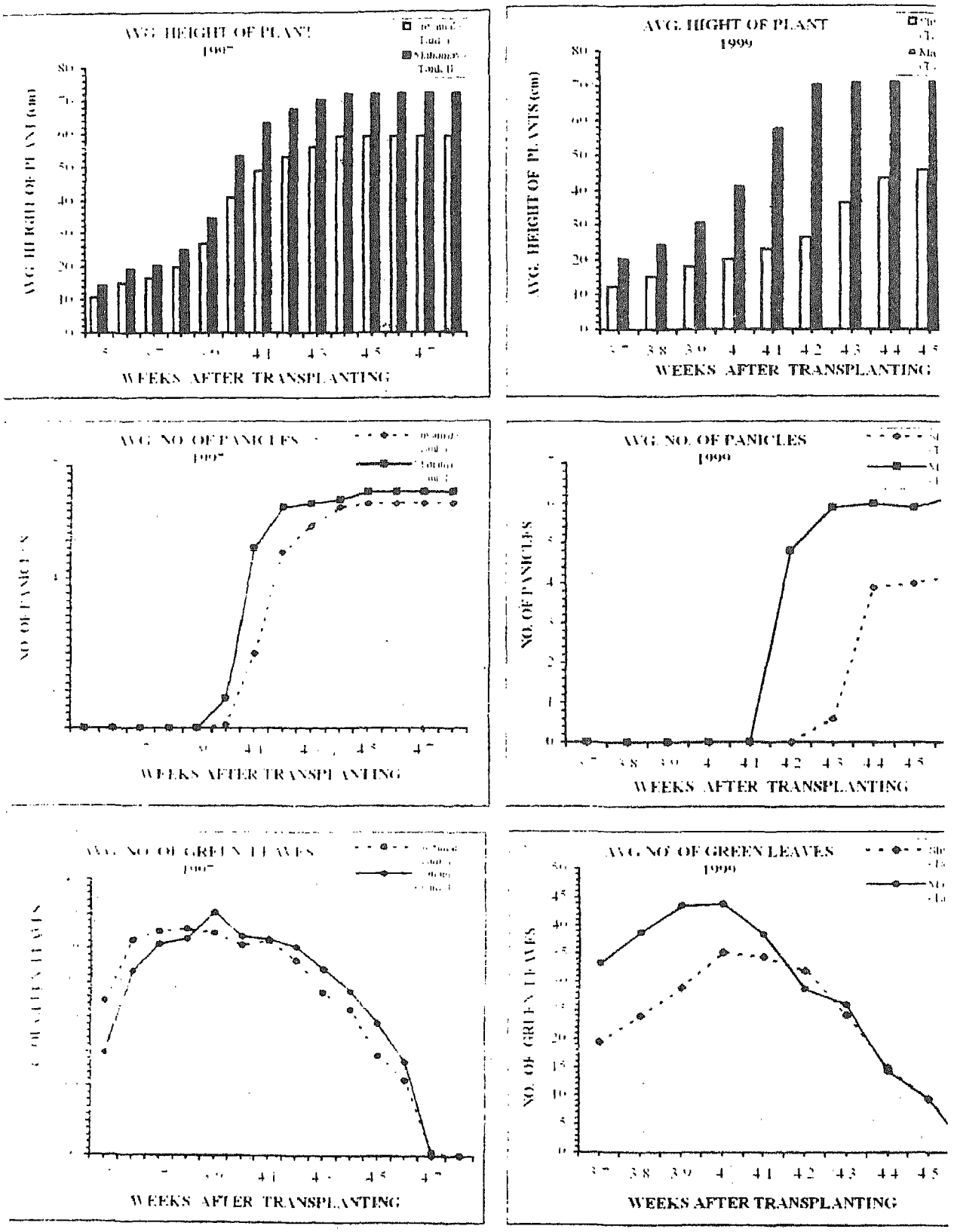

Fig. 4. Variation of height, number of green leaves and number of panicles of Shyamala and Mahamaya in 1997 and 1999

The average weight of 100 grains was 2.80 and 2.76 gm under Shyamala genotype and 3.28 and 3.21 gm under Mahamaya genotype in the year 1997 and 1999, respectively. Grain yield was 24.3 and 20.8 q/ha from tanks and 15.5 and 16.7 q/ha from field under Shyamala genotype whereas it was 24.3 and 79.8 q/ha from tanks and 32.5 and 30.4 q/ha from field under Mahamaya genotype during the year 1997 and 1999, respectively. Dry biomass yield was 62.5 q/ha from tank and 51.2 q/ha from field under Shyamala genotype and 83.3 q/ha from tank and 83.1 from field under Mahamaya genotype during 1997. During 1999, dry biomass yield from the tank was 138.8 q/ha under Shyamala genotype and 236.1 q/ha under mahamaya genotype (Table 1). Harvest index of the season from the tank was 0.4 and 0.15 under Shyamala genotype and 0.3 and 0.34 under Mahamaya genotype during 1997 and 1999, respectively.

Conclusion

The study revealed that difference in weekly mean canopy temperature as well as soil temperature between Shyamala and Mahamaya genotypes at 10 and 50 cm height and 5 and 20 cm soil depths were positive in general and ranged between 0.1 to 1.5°C during active vegetative, flowering, grain formation and maturity stages except for few weeks i.e., between 44th to 48th weeks when values were found negative. This was due to higher LAI, plant height and more number of green leaves and tillers observed in Mayamaya compared to that of Shyamala. The higher canopy as well as soil thermal regimes under Shyamala has resulted in more consumptive use of water and significant reduction in yield of Shyamala genotype. The water use efficiency (WUE) of Mahamaya variety was more in both the years than that of Shyamala variety. This indicates that

Table 1. Grain yield and dry biomass of Shyamala and Mahamaya at Raipur

		1997		1999	
		Tank-I II	Whole Field	Tank-I II	Whole Field
Area : a (sq. meter)	**Shyamala**	**1.44**	**1443.74**	**1.44**	**703**
	Mahamaya	1.44	1443.74	1.44	703
Dry biomass wt. In gms : b	**Shyamala**	**900**	**370**	**2000**	**—**
	Mahamaya	1200	600	3400	—
dry biomass yield q/ha : c = b/10a	**Shyamala**	**62.5**	**51.2**	**138.89**	**—**
	Mahamaya	83.3	83.1	236.11	—
Grain wt. in gsms. : d	**Shyamala**	**350**	**1120**	**300**	**117100**
	Mahamaya	350	2350	1150	216650
Weight of 100 grains	**Shyamala**	**2.80 gms.**		**2.76 gms.**	
	Mahamaya	3.28 gms.		3.21 gms.	
Grain yield in q/ha, e=d/10a	**Shyamala**	**24.3**	**15.5**	**20.83**	**16.66**
	Mahamaya	24.3	32.5	79.86	30.39
Avg. grain yield (Tanks) q/ha	**Shyamala**	**24.3**	**—**	**20.83**	**—**
	Mahamaya	24.3	—	79.86	—
Avg. grain yield (Field) q/ha	**Shyamala**	**—**	**15.5**	**—**	**16.66**
	Mahamaya	—	32.5	—	30.39
Harvest index, e/c	**Shyamala**	**0.4**	**0.3**	**0.15**	**—**
	Mahamaya	0.3	0.4	0.34	—

Mahamaya genotype is superior and may be recommended to the farming community for getting better crop yields.

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