SUITABILITY OF UPLAND RICE CULTIVARS (*Oryza sativa* L.) FOR SHADED SITUATIONS

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Dedicated to

The farming community

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DECLARATION

I hereby declare that this thesis entitled "**Suitability of upland rice cultivars (*Oryza sativa* L.) for shaded situation**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,

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CERTIFICATE

Certified that this thesis entitled "**Suitability of upland rice cultivars (*Oryza sativa* L.) for shaded situation**" is a record of research work done independently by Mr. Sunilkumar, B. (98-11-06) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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LIST OF ABBREVIATIONS

@	at the rate of
^0C	Degree Celsius
B : C	Benefit : Cost
cm	Centimeter
DAS	Days after sowing
DMP	Dry matter production
Fig.	Figure
FYM	Farmyard manure
g	gram
ha	hectare
HI	Harvest index
K	Potassium
kg	kilogram
kg ha^{-1}	kilogram per hectare
LAD	Leaf area duration
LAI	Leaf area index
m	meter
m^2	square meter
mg	Milligram
N	Nitrogen
NAR	Net assimilation rate
P	Phosphorus
RGR	Relative growth rate
Rs.	Rupees
RWC	Relative water content
Si	Silicon
SLW	Specific leaf weight
t	Tonnes
%	per cent

INTRODUCTION

1. INTRODUCTION

Rice, the staple food of Keralites is ironically one of the fast disappearing crops of the state. The present production level of 8.7 lakh tonne of rice is only just enough to meet 25 per cent of our demand (Land Use Board, 1997). So, the rice production has to be increased at least by four times to meet the present requirement. At Present we are witnessing large-scale conversion of paddy lands for more remunerative crops and non-agricultural purposes like construction of houses. The scope of expanding the area under low land rice being limited, it is high time to explore the possibility of growing rice as a component in our homesteads and converted paddy lands and other intercropping situations involving annuals and perennials. This necessitates bestowing more thrust on upland rice culture.

On a global basis, upland rice culture accounts for 60 per cent of the coverage and on all India basis, it is 30 per cent. An yield potential of 7 t ha^{-1} was realised for upland rice in Philippines and the potential productivity realised in Nigeria was 5.4 t ha^{-1}. Maximum productivity of rice obtained in Kerala under upland condition was 4 t ha^{-1} (Valarmathi, 1996).

Solar radiation being the most limiting factor in determining the productivity of any intercropping system, it is essential to study the response of different rice cultivars to varying levels of shade. Viji (1995) reported that Swarnaprabha and Co-43 maintained higher grain yield even under low light condition compared to IR-20. The tiller mortality and sterility per cent were lesser in Swarnaprabha and Co-43 than IR-20. Since upland cultivars are more susceptible to lodging and drought situations, the role of Si, which imparts resistance to lodging and tolerance to water stress has to be assessed.

Many scientists report the possibility of intercropping rice with other crops. Intercropping of rice cultivars Cauvery and CR-42-38 in between the rows of sugarcane yielded 3.24 and 2.29 t ha^{-1} respectively with out ~~adversely~~ affecting the cane yield (Sankaranarayan and Sahi, 1980). Study conducted by Kerala Agricultural University revealed the possibility of raising rice in coconut garden (KAU, 1984). Intercropping of upland rice with short duration grain legumes has shown promising productivity and resource use efficiency (Agarwal *et al.*, 1992).

Rice is a known Si accumulator (Takahashi, 1995). Several beneficial effects have been attributed to Si in the physiology of the rice plant. It is found that Si gets deposited on the cell walls of the stem, there by increases culm strength and prevents the tendency to lodge. The increase in Si content of the cells also results in increased resistance of the plant to the attack of pests and diseases. Further more Si is said to regulate the rate of transpiration, there by enable the plant to with stand drought conditions better.

With this background the study was undertaken with the following objectives.

1. To study the effect of varying solar radiation intensities on upland rice.
2. To assess the suitability of different rice cultivars for shaded upland situation.
3. To study the effect of silica on growth and productivity of upland rice.
4. To study the impact of silica on upland rice in shaded situation.
5. To work out the economics of silica application.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Solar radiation, which is the major source of light energy, is the main input of the photosynthetic process in the green plants. Quantity, quality and duration of solar radiation influence the growth and development of crop plants. When water and nutrients are not limiting, the yield of rice is mostly influenced by solar radiation. But cultivars differ in their ability to with stand shaded situations. Growth and physiological characters help some cultivars to grow and yield better in low light stress condition. Silicon, a beneficial nutrient of rice, helps them to tolerate the low light stress by improving light penetration by producing erect leaves. Literature pertaining to the influence of solar radiation and Si on the growth and productivity of rice are reviewed in this chapter.

2.1 Influence of light on morphological parameters of rice

Under low light condition the height of the rice plant was increased approximately by 15 per cent (Venkateswarlu *et al.*, 1977). The increase is reported to be more apparent in tall Indica late cultivars than in early cultivars under subdued light. Increase in plant height under low irradiance was mainly due to increased synthesis of gibberelic acid in popular high yielding rice cultivars (Tanaka *et al.*, 1966; Venkateswarlu, *et al.*, 1977, Janardhan and Murty, 1980; Murty and Murty, 1981).

Low irradiance reduced the tillering capacity to an extent of 13.0 to 50.0 per cent (Murty *et al*, 1976; Singh *et al.*, 1988) with increased rate of production of weak tillers (Venkateswarlu, 1977). The higher the light intensity lesser is the reduction in the number of tillers. The reduction in number of tillers at 50 per cent of natural light ranged from 40-50 per cent of the control (Venkateswarlu, 1977). He also observed that low light tolerant varieties RP 4-14 accounted for only 18.2 per cent reduction in tiller number under subdued light condition while Sona a low light susceptible variety registered 35 per cent reduction. Tiller production was reduced by 10 per cent in early types but in certain cultivars like Mashuri, (tall indica) No. 587-4 (a mutant) and IR-8 the tiller production was increased upto 10 per cent (Janardhan and Murty, 1980). Viji (1995) studied shade tolerance of rice cultivars and found that leaf area index and chlorophyll content increased in shaded situation.

The dry matter accumulation in rice in general is negatively influenced by the subdued light (Tanaka *et al.*, 1966; Thangaraj and Sivasubramanian, 1990). Rice (cv Ratna) plants grown under low irradiance of 50 per cent of normal light during active tillering and panicle initiation stages reduced the dry matter accumulation to the magnitude of 12.97 per cent over control (Dineshchandra *et al.*, 1986). Similarly, Janardhan and Murty (1980) accounted about 53 per cent reduction in total dry matter production (DMP) due to low irradiance at vegetative stage in the rice cultivar mutant No. 587-4. They also suggested that DMP under low light was impaired through reduced photosynthetic rate. Low irradiance provided during the critical reproduction and ripening stages reduced the DMP considerably at harvest (Singh *et al.*, 1988).

2.2 Influence of light on yield components and grain yield of rice

Yoshida and Parao (1976) indicated that spikelet number per m^2 alone explained 60 per cent of yield variations, where as the combinations of all the components accounted for 81 per cent of variation. Filled grain per panicle and grain weight together accounted for 21 per cent of variation. Influence of light intensity on panicle production (Nayak and Murty, 1980) and grain filling (Venkaleswaralu *et al.*, 1977; Thangaraj and Sivasubramanian, 1993) were reported. A reduction in panicle number due to shading during the vegetative and reproductive phases was reported by Sreedharan (1975).

Reduction in grain number per panicle under subdued low light situation was reported by Matsushima *et al.* (1967) and Venketeswaralu *et al.*, (1977). They indicated that shading significantly reduced the grain number in wet season irrespective of growth phase; but the reduction was critical during the reproductive phase. The reduction test grain weight under low light was comparatively lesser compared to other yield components (Sahu and Murty, 1976; Nayak and Murty, 1980; Thangaraj and Sivasubramanian, 1990).

Subdued light affected the grain filling either by increasing the number of degenerated spikelets or by impairing grain filling (Matsuhima, 1957; Thangaraj and Sivasubramanian, 1990). Later many other workers also reported enhanced spikelet sterility under low light conditions (Yoshida and Parao, 1976; Venkateswarlu *et al.*, 1977 ; Thangaraj and Sivasubramanian, 1990 ; Viji, 1995). Murty and Murty (1981) reported considerably higher sterility under continuous shading. Sikder and Gupta (1979) observed higher values on yield attributes and yield in boro (January-April) than in Kharif (July- November).

Thangaraj and Sivasubramanian (1993) demonstrated a close association between grain yield and solar radiation. In an analysis with short and medium duration varieties, Murty *et al.* (1975) reported an yield loss of 3.5 per cent in short and about 53 per cent in medium duration types in wet season compared with dry season planting. However, between these two groups, varietal differences were also significant.

Patro and Sahu (1986) reported that reduction of mature grain was impaired due to poor filling of grains, which reflected in the reduction of thousand grain weight. Light stress imposed for more than one stage of growth, particularly reproductive and ripening stages reduced the dry matter, grain number and grain yield by about 50% with increased spikelet sterility (Singh *et al.*, 1988). Reduction in grain yield was also observed by Vijayaleksmi *et al.*, 1987 and Thangaraj and Sivasubramanian (1993).

The lower grain yield under shade was due to the cumulative effects of reduction in the number of panicles per unit area, number of grains per panicle and 1000 grain weight and increased sterility as documented by Murty *et al.*, 1975, Nayak and Murty, 1980 and Patro and Sahu (1986).

Later stages of light stress induced high percentage of spikelet sterility and reduced filled grain as well as 1000 grain weight. These impaired yield components due to light stress is mainly due to limitations in the translocation of current or reserve photoassimilate (Nayak *et al.*, 1979).

Dash and Rao (1990) suggested that stability in grain number per panicle, fertility percentage, harvest index, dry matter and grain yield were associated with tolerance to subdued light. In rice low light affects yield components like panicle number per hill, grain number per panicle, filled spikelets percentage as well as 1000-grain weight (Murty *et al.*, 1975; Murty and Sahu, 1986).

Viji (1995) studied the shade tolerance of three cultivars (Swarnaprabha, Co-43, and IR-20) and found that number of productive tillers, spikelet number, grains per panicle and thousand-grain weight were greatly influenced by low light. Among three cultivars Swarnaprabha and Co-43 were reported as low light tolerant cultivars because of their lesser tiller mortality and sterility percentage. Shade tolerance of rice cultivars was also studied by Janardhan and Murthy (1978) and Nayak *et al.* (1979).

2.3 Influence of light on physiological characters of rice

Low light stress reduced the specific leaf weight (SLW) by 25 per cent especially at early growth stages (Murty *et al.*, 1973). Cultivar variations were also observed with tall indicas showing higher SLW values (Janardhan and Murty, 1980).

Crops shaded during the vegetative phase were smaller and had a lower Leaf Area Index (LAI) and hence had better light penetration than the control (Yoshida and Parao, 1976). LAI is reported to be reduced to a greater extent in plants shaded either from planting to panicle initiation or from flowering to harvest (Sreedharan and Vamadevan, 1981). Shading also caused death of many lower leaves (Nawasero and Tanaka, 1966).

Murata (1961) reported that the relative growth rate (RGR) and leaf area were practically free from the influence of solar radiation as long as the level of radiation was higher than the one-third of the full incident radiation. Subdued light decreased the relative growth rate (RGR) and net assimilation rate (NAR) by 36 and 52 per cent respectively. On the contrary, leaf area ratio and relative leaf growth rate (RLGR) increased under low light situations (Janardhan and Murty, 1980). Viji (1995) reported a decrease in SLW, RGR, CGR, NAR and chlorophyll a/b ratio when rice cultivars were subjected to 50 per cent shade.

Under low light levels the association between stem weight ratio at flowering and yield was positive. Stem weight losses were higher under low light indicating that the natural balance between source and sink is disturbed under low light stress (Dass and Ratnam, 1989). Low light intensity increased the mesophyll resistance (Raven and Glidewell, 1981) and stomatal resistance (Peet, 1976). The progressive increase in diffusion resistance with decrease in light intensity was observed by Akita and Moss (1973). Low light intensity is reported to decrease water potential and transpiration rate and to increase the diffusion resistance of the peanut leaves progressively at all the stages of crop growth (Jadhav, 1992). The leaf vascular bundle and midrib of shaded leaves were examined to be larger in area and thinner in size than in control (100% light). The non-shaded leaves were typically thicker than shaded leaves because they formed longer pallisade parenchyma (Salisbury and Ross, 1978).

2.4 Influence of light on chlorophyll status of rice

The chlorophyll concentration of rice leaves increased under shade (Janardhan and Murty, 1980; Thangaraj and Sivasubramanian, 1990; Voleti *et al.*, 1991; Viji, 1995). The increase was more predominant in chlorophyll b fraction leading to a lower chlorophyll a/b ratio (Murty *et al.*, 1975; Venkateswarlu, 1977; Chowdhury *et al.*, 1994). Murty *et al.* (1976) and Singh (1994) showed that the adaptability of rice cultivars to low light was associated with high chlorophyll content.

2.5 Influence of light on root characters of rice

Kawata and Saejima (1978) observed the production of more short unbranched roots by shading. Under subdued light translocation of carbohydrates from the shoots to the root of rice plant appeared to be much reduced (Mengel and Viro, 1978) because of reduction in photosynthetic rate by 20-35 percent in the middle and lower leaves (Sato and Kim, 1980). Low light intensity damaged the roots more seriously than other organs in rice (Wang *et al.*, 1981). Efficiency of 'N' uptake was also severely affected by shading (Tatsumi and Kono, 1980).

2.6 Influence of silicon on plant growth

Investigations on the effect of silicon on the growth and yield of crops date back to the era of Liebig (1840). He regarded silicon as a necessary element in plant nutrition. Experimental evidence for the function of silica as promoter of growth and yield was perhaps first furnished by Wolff and Kreuzhage (1884). Onodera (1927) noticed better growth of paddy with silicic acid treatment, whereas Winifred *et al.* (1927) obtained increase in the number of tillers due to Si application. The work of Okawa and Kinsaku (1936), revealed the influence of slilicic acid on increased growth and yield of rice plant. Sreenivasan (1936) reported increase in height, dry matter production and root length by application of sodium silicate in conjunction with green manure.

However, Yoshida *et al.* (1962) reported that Si was not essential for the growth and tillering of rice, but was beneficial during the reproductive stage and for good grain out put. Silica also increased the height of plant, root length and number of tillers.

Fritz (1940) observed in water culture experiment that deficiency of silica caused depression of root and shoot growth in cereals. Ishibashi and Hajima (1937), Okamoto (1957) and Azuma *et al.* (1961) reported an increase in the dry matter production, height of plants and the length of ear head and root by the addition of silica to rice.

Mitsui (1956) observed the importance of Si in hastening panicle growth and increasing panicle weight. Miyoshi and Ishii (1960) also found that Si increased the number of tillers, DMP and translocation from straw to ear. It also enhanced panicle growth and increased panicle weight. Okamoto (1970) reported that the supply of silica increased the height of plants, number of leaves, leaf size, number of vascular bundles in the culm, rate of protoplasmic translocation in the root hairs and the thickening of the lowest elongated internode.

Later from several studies, it appears that Si nutrition has direct and indirect beneficial effects on the rice growth largely due to its unique physiological role (Okuda and Takahashi, 1965; Yoshida, 1975; Takahashi *et al.*, 1990). The positive effect of an adequate supply of Si on leaf erectness can be beneficial especially when rice plant density is high and low light intensity is likely to limit photosynthesis (Yoshida et *al.*, 1969; Kang,1985).

In a study on the effect of silicon at various stages of plant growth, Takahashi (1961) concluded that absence of Si in vegetative stage led to decrease in the top growth, number of tillers as well as fresh and dry weight. According to Agarie *et al.* (1992) the maintenance of photosynthetic activity due to Si fertilization could be one of the reasons for the increased dry matter production. They also observed an increase in water use efficiency in Si amended rice plants probably due to prevention of excessive transpiration.

Si fertilization benefits rice plants in the nursery (at seedling stage) as well as in the field after transplanting. In field experiments various slag applied to nursery plants increased the number of leaves and dry matter produced by rice plants (Lee *et al.*, 1985). After transplanting Si fertilization increased the number of tillers and panicles (IRRI, 1965; Kim *et al.*, 1985; Liang *et al.*, 1994). A similar beneficial effect of applied Si on tiller number and grain filling has been reported by Burbey *et al.*, (1988) in upland rice (Vr. Danaubawah) grown on Ultisol in West Samatra. The effect of Si supply on the growth of rice plants seems to be most remarkable during the reproductive growth stage (Ma *et al.*, 1989). Si also has a positive effect on the number of spikelets on secondary branches of panicles and the ripening of grains (Seo and Ota, 1983; Lee *et al.* 1990). Apparently Si plays an important role in hull formation, which in turn seems to influence grain quality. The hulls of poor quality milky- white grains (kernels) are generally low in Si content, which is directly proportional to the Si concentration in the straw (Mizuno, 1987)

2.7 Effect of silicon on yield and yield contributing characters

Silicate slag application at an optimum rate of 1.5- 2 t ha^{-1} is now widely used in degraded paddy fields and peaty paddy fields in Japan (Kono, 1969; Takahashi and Miyake, 1977). Yield increase of 10% are common when Si is added and at times exceed 30% when leaf blast is severe (Yoshida, 1981). An acid weathering sequence of soils suggests that, due to desilication, soils (minerals) lose Si as a result of leaching (Friesen *et al.*, 1994). Sub tropical and tropical soils (Inceptisols, Alfisols, Ultisols, and Oxisols) in sub humid to humid climate are generally low in plant available Si and would benefit from Si fertilization (Kawaguchi, 1966; Takijima and Gunawardena, 1969; Tanaka and Yoshida, 1970; Foy; 1992).

In 1963, IRRI scientists conducted a field experiment during the dry season to investigate the effect of Si fertilization on yields of the rice varieties (Chianung and Peta) (IRRI, 1965). The Si applied basally at 45 kg ha^{-1} as calcium magnesium silicate significantly increased the grain yields by more than 500 kg ha^{-1}.

Liang *et al.* (1994) reported increase in rice yield from about 4.6 to 20.7per cent with an average increase of 10% ($p<0.01$) due to the basal application of a new silicate fertilizer (containing 230 g water-soluble Si per kg) to calcareous soils (upto 8.9% $CaCO_3$). Haroda and Takata (1957) obtained fourteen per cent increase in grain yield from a soil having a low SiO_2/P_2O_5 ratio by adding calcium silicate. Kido (1958) opined that thousand grain weight was increased by application of calcium silicate. In a study on the effect of silicon at various stages of plant growth, Takahashi (1961) concluded that absence of silicon in the reproductive phase caused a decrease in the number of spikelets per panicle and percentage of ripe grains. Money (1964) in a pot culture experiment reported marked increase in grain yield of rice due to the application of silica in the form of magnesium silicate. Padmaja and Varghese (1964) observed significant increase in yield of grain and straw by the application of magnesium and silica to rice crop in Vellayani soil. Vijayakumar and Koshy (1977) found an increase in the thousand-grain weight by the application of magnesium silicate for rice in pot culture experiment using Vellayani Kayal soil. Lawes (1951) found that sodium and potassium silicate were equally effective in increasing the yield of rice. Kido (1958) opined that thousand grain weight was increased by the application of calcium silicate.

Field experiment conducted with IR-8 at Polonnaruwa in Sri Lanka has shown that rice hull ash application of 0.74 t ha^{-1} with the recommended level of fertilizers (69:20:18 kg NPK ha^{-1}) yielded an additional 1.0-1.4 t ha^{-1}, whereas further increase in ash additions decreased the yield (Amarasiri, 1978). Amendment of a saline-acid soil by rice hull ash increased rice yield only in the first year of application (Disathaporn *et al.*, 1989).

Beneficial effects of applied Si on yields of upland rice have been observed in the Philippines (Garrity *et al.*, 1990), Colombia (Correa-Victoria *et al.*, 1994; Friesen et al., 1994), China (Liang et al., 1994) and West Africa (Yamauchi and Winslow, 1989; Winslow, 1992). Garrity et al. (1990) found that Si application as rice hulls (9.4 per cent Si) or its ash (44.4 per cent Si) increased the yield of rice in ultisol with very high P-fixing capacity at Cavinti, Laguna and Philippines. Application of 18.7 g Si m^{-2} as sodium matasilicate increased the grain yield of upland rice by 48 per cent (Winslow, 1992). Recent results of field studies clearly indicated that Si deficiency is a major soil nutrient constraint limiting upland rice yield by about 40 per cent (600-900 kg ha^{-1}) on highly weathered savanna soils in Colombia (Friesen *et al.*, 1994).

2.8 Role of proline in plants

Accumulation of proline occurs in leaves subjected to drought. Several workers suggested that proline content could be used as a measure of drought resistance (Barnett and Naylor, 1996, Singh *et al.*, 1972). Parker (1968) suggested that proline accumulation could not be taken as a protective mechanism against drought but might have resulted from some protein breakdown or it might simply be a storage compound of N. Naylor (1972) reported that water stress led to blockage in the synthesis of some amino acids at one or more points in the metabolic pathway. More negative values of leaf water potential were associated with higher amount of free proline in wheat cultivars (Karamanos *et al.*, 1983) and it was evident that the increased amounts of free proline could be associated with more effective dehydration and drought avoidance mechanism.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The investigation entitled "suitability of upland rice cultivars for shaded situations" was undertaken to assess the response of four rice varieties under three levels of shades and two levels of silica in upland situation. The materials used and the modus operandi of the study are briefly described below.

3.1 Materials

3.1.1 Experimental site

The experiment was conducted at the Instructional farm (IF), attached to the College of Agriculture (CoA), Vellayani located at 8.5^0 N latitude, 76.9^0 E longitude and at an altitude of 29 m above mean sea level.

3.1.2 Soil

The data on physico-chemical properties of the soil (Rhodic Haplustox) of the experimental site are furnished in table.

3.2 Physico-chemical properties of the soil

A. Mechanical composition

Sl. No.	Constituents	Content in soil (per cent)	Method used
1	Coarse sand	14.2	Bouyoucos Hydrometer method (Bouyoucos,1962)
2	Fine sand	33.3	
3	Silt	27.4	
4	Clay	25.1	

Texture - Sandy clay loam

Plate 1. General view of experimental field

B. Important physico-chemical characters

Sl. No	Parameters	Content	Rating	Method used
1	Available N (kg ha^{-1})	231.5	Low	Alkaline potassium permanganate method (Subbiah and Asija,1956)
2	Available P_2O_5 (kg ha^{-1})	33.8	Medium	Bray colorimetric method (Jackson,1973)
3	Available K_2O (kg ha^{-1})	51.9	Low	Ammonium acetate method (Jackson,1973)
4	pH	5.2	Acidic	pH meter with glass electrode (Jackson,1973)
5.	Field capacity (per cent)	24.6		Core sampler (Dastane,1967)

3.3 Cropping history of the field

During the previous season (summer), a bulk crop of cowpea was cultivated in the experimental field.

3.4 Season

The study was conducted during the Kharif season of 1999.

3.5 Weather data

The meteorological data including mean values of temperature, relative humidity and rainfall during the cropping period was collected from the Agrometeorological observatory attached to the Department of Agronomy, College of Agriculture, Vellayani and are presented in Appendix I.

3.6 Crop and Variety

Upland rice cultivars like Swarnaprabha, Matta Triveni and pre released cultures viz., A 4-4-2 and A 4-1-3 were selected for the experiment. Details of the varieties are shown in the table.

Varieties	Duration (days)	Parentage	Characteristics
Swarnaprabha	100-105	Bhavani/Triveni	Suited for upland (modan) and for all the three seasons in the wet lands. Resistant to blast susceptible to sheath blight and bacterial leaf blight. Moderately resistant to stem borer and drought
Matta Triveni (PTB-45)	100-105	Reselection from Triveni	Suitable for direct seeding and transplanting, moderatively resistant to BPH, susceptible to blast and sheath blight
A4-1-3	100-105	M. 210/PTB 28	Suitable for direct seeding in upland
A4-4-2	105-110	M. 210/PTB 28	Suitable for direct seeding in upland, moderately resistant to blast, ear head bug and BPH.

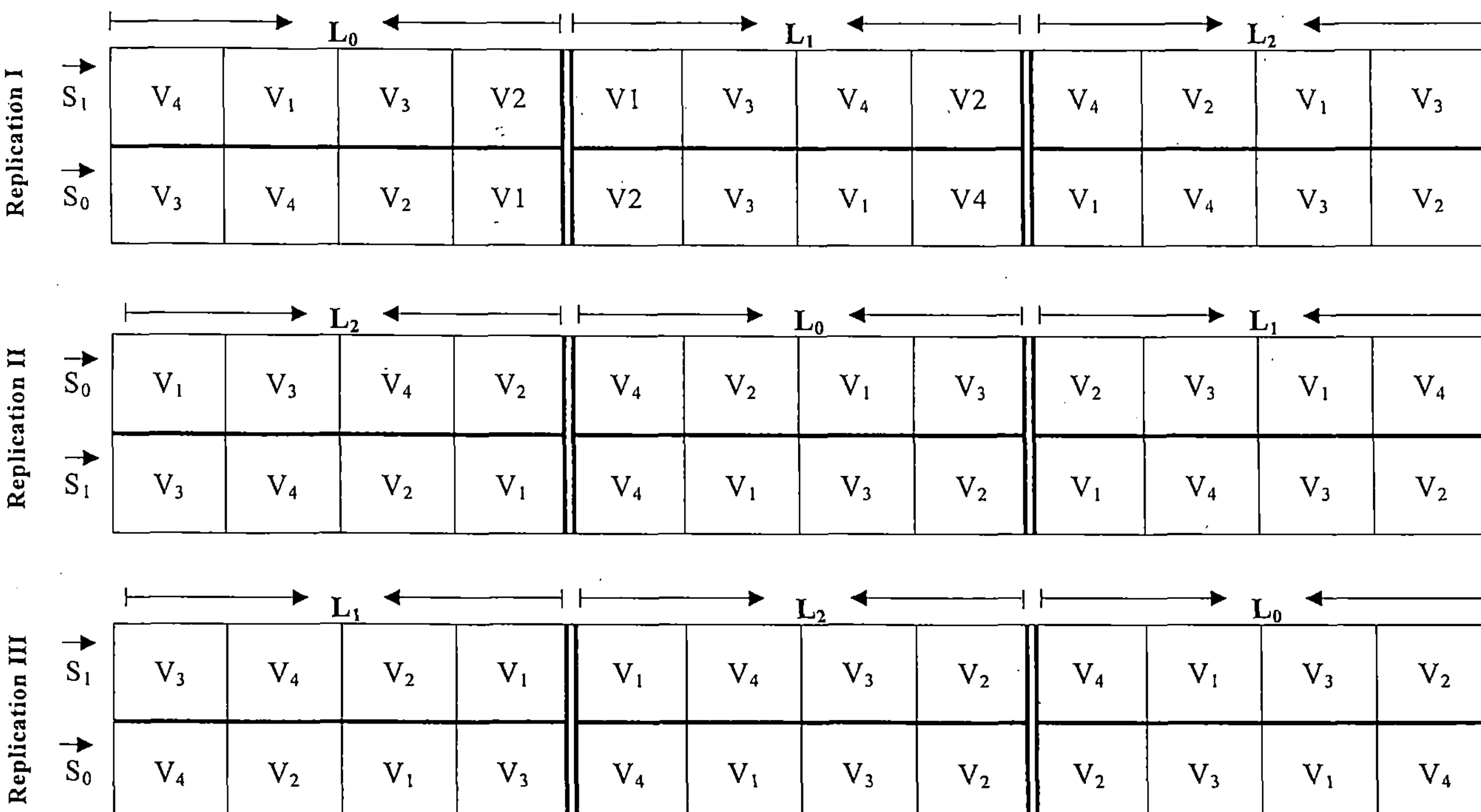
3.6.1 Sources of seed materials

The seeds of the above rice varieties were collected from Regional Agricultural Research Station (RARS), Pattambi.

3.7 Source of silica

Sodium silicate was used as the source of silicon. It was purchased @ Rs. 44 per kg. In order to compensate the effect of sodium in sodium

Fig. 1 Layout plan of the experiment



silicate, sodium carbonate was applied in other plots on equivalent basis. The cost of sodium carbonate was Rs. 65 per kg.

3.8 Manures and Fertilizers

Farm yard manure (FYM) (0.4, 0.3 and 0.2 per cent N, P_2O_5 and K_2O respectively) was used as the organic nutrient source. Urea (46.2 per cent N), Mussoriephos (21.8 per cent P_2O_5) and Muriate of potash (59.8 per cent of K_2O) were used as the sources of nitrogen, phosphorus and potassium respectively. Sodium silicate (49.5 per cent SiO_2) was used as source of silica. In order to compensate the effect of sodium in sodium silicate, sodium carbonate was applied in other plots.

3.9 Methods

3.9.1 Design and lay out

Design	Split-split plot
Replications	3

3.9.2 Treatment details

Treatment combinations - 24

(Combinations of three levels of shade, two levels of silica and four cultivars formed 24 treatment combinations)

3.9.2.1 Shade levels

L_0 - 0 per cent shade (open)

L_1 - 20 per cent shade

L_2 - 40 per cent shade

3.9.2.2 Silica levels

S_0 - Zero Si O_2 or No Si O_2

S_1 - 100 kg ha $^{-1}$ Si O_2

3.9.2.3 Cultivars

V_1 - Swarnaprabha

V_2 - A 4-4-2

V_3- A4-1-3

V_4- Matta Triveni

3.9.3 Plot size

Gross plot size - 3.2 x 1.8 m

Net plot size - 3 x 1.5 m

(One row of plants on the border of the plot kept as border row)

3.10 Field Culture

The experimental field was ploughed manually, stubble were removed and levelled properly. The field was then laid out into blocks and plots.

3.10.1 Manures and fertilizers

FYM @ 20 t ha^{-1} was applied uniformly in all the plots and mixed well with top soil. Fertilizers were applied as prescribed in the package of practice recommendations of Kerala Agricultural University (60: 30: 30 kg NPK ha^{-1}). Full dose of phosphorus, 1/3 of potassium and 1/3 of nitrogen were applied as basal and the remaining dose of nitrogen and potassium were given at 30 DAS and 60 DAS. Full dose of SiO_2 @100 kg ha^{-1} was applied as basal. In order to compensate the effect of Na in sodium silicate applied plots $NaCO_3$ was applied in other plots as basal dose.

3.10.2. Sowing

Seeds were soaked for 24 hr and the soaked seeds were dibbled in the next day at a spacing of 20 x 10 cm. Sowing was done on 16.06.1999.

3.10.3 Erection of shade net

Shade was imposed on the day of sowing by using shade nets of the appropriate shade level.

3.10.4 After cultivation

Almost uniform germination was obtained. Gap filling and thinning were done two weeks after sowing. The crop was given two hand weedings, one at 30 DAS and another at 60 DAS. At 30 DAS 10 plants were selected randomly from each plot and tagged as observational plants.

3.10.5 Irrigation

The crop was irrigated uniformly in alternate days.

3.10.6 Plant protection

Ekalux 25 EC @ 750 ml ha^{-1} was applied against leaf roller (*Cnaphalocrocis medinalis*) and stem borer (*Scirpophaga incertulas*). Metacid 50 EC @ 500 ml ha^{-1} was applied against *Leptocorisa acuta.* Rodent control measures were adopted as and when necessary by using warfarin cake.

3.10.7 Harvesting

Varieties A 4-4-2 and Matta Triveni grown in open situation were harvested at 110 days after sowing and the remaining crop was harvested at 125 days after sowing.

3.11 Biometric observations

3.11.1 Growth characters

3.11.1.1 Height of the plant

The mean value of the height of 10 randomly selected observational plants was computed at 30 DAS, 60 DAS and at harvest. The height was measured from the base of the plant to the tip of the longest leaf or to the tip of the longest ear head which ever was taller.

3.11.1.2 Number of tillers per hill

Total number of tillers per hill was recorded at 30 DAS, 60 DAS and at harvest. Ten hills were selected diagonally from the net plot area and tillers produced in each hill were counted and expressed as number of tiller per hill.

3.11.1.3 Dry matter production

Dry matter production was recorded at 30 DAS, 60 DAS and at harvest. The sample plants were dried at 70^0C for 48 hr. and weighed and expressed as t ha^{-1}. Drying and weighing were repeated till constant weights were obtained.

3.11.1.4 Culm strength

The procedure of Atkins (1938) was adapted for computing culm strength. Crop was harvested at ground level and dried for some time and was cut in equal length and made into bundles and weighed. The culm strength was expressed in mg cm^{-1}

3.11.2 Observation on yield attributes and yield

3.11.2.1 Length of panicle

Twelve panicles were selected randomly from the net plot and the lengths were measured and the mean value was computed as length of panicle and expressed in cm.

3.11.2.2 Weight of panicle

Twelve panicles were selected randomly from the net plot and the weight was measured and the mean value was computed as weight of panicle and expressed in g.

3.11.2.3 Number of productive tillers per hill

Numbers of productive tillers were recorded at harvest. Ten hills were selected diagonally from the net plot area and productive tillers in each hill were counted and the mean value was calculated and was expressed as number of productive tillers per hill.

3.11.2.4 Number of spikelets per panicle

The numbers of spikelets in twelve panicles collected randomly from the net plot were counted and the mean value was expressed as number of spikelets per panicle.

3.11.2.5 Number of filled grains per panicle

The numbers of filled grains in twelve panicles collected randomly from the net plot were counted and the mean value was expressed as number of spikelets per panicle.

3.11.2.6 Chaff percentage

The chaff percentage was worked out by using the formula.

$$\text{Chaff percentage} = \frac{\text{Number of unfilled grains}}{\text{Total number of grains}} \times 100$$

3.11.2.7 Thousand grain weight

Thousand grains were drawn from each net plot, dried to constant weight and the weight was recorded in g.

3.11.2.8 Grain yield

The grain harvested from each net plot were dried to constant weight, cleaned, weighed and expressed as kg ha^{-1}.

3.11.2.9 Straw yield

The straw harvested from each net plot was dried to constant weight under sun and the weight was expressed as kg ha^{-1}.

3.11.2.10 Harvest index

Harvest index was calculated using the formula

$$\text{Harvest Index (HI)} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.11.3 Physiological characters

3.11.3.1 Crop growth rate (CGR)

CGR was computed using the formula of Watson (1958) and expressed in g m^{-2} day^{-1}.

$$CGR = \frac{W_2 - W_1}{P\,(t_2 - t_1)}$$

W_1 and W_2 - Whole plant dry weight at t_1 and t_2

$(t_2 - t_1)$ - time interval in days.

P - Ground area on which W_1 and W_2 have been estimated.

3.11.3.2 Relative growth rate (RGR)

The RGR was determined based on the formula of Williams (1946) and expressed in mg g^{-1} day^{-1}.

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where, W_1 and W_2 - Plant dry weight at time t_1 and t_2 respectively

$t_2 - t_1$ - Time interval in days

3.11.3.3 Net assimilation rate (NAR)

The method proposed by Gregory (1917) and modified by Williams (1946) was employed for calculating the NAR on leaf dry weight basis and the values were expressed as mg cm^{-2} day^{-1}.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e L_2 - \log_e L_1}{L_2 - L_1}$$

Where,

W_1 and W_2 - plant dry weight at t_1 and t_2 respectively

L_1 and L2 - Leaf area at t_1 and t_2 respectively

$t_2 - t_1$. Time interval in days

3.11.3.4 Specific leaf weight (SLW)

The SLW was calculated by employing the formula suggested by Pearce *et al.* (1968) and is expressed in mg cm^{-2}.

$$SLW = \frac{\text{Leaf dry weight}}{\text{Leaf area}}$$

3.11.3.5 Leaf area duration

Leaf area duration (LAD) was calculated using the formula given by Power *et al.* (1967).

$$LAD = \frac{Li + (Li + 1) \times (t_2 - t_1)}{2}$$

Li	=	LAI at first stage
Li + 1	=	LAI at second stage
$t_2 - t_1$	=	Time interval between these stages

3.11.3.6 Leaf area index (LAI)

Leaf area at 30 DAS and 60 DAS was recorded by using the length width method suggested by Gomez (1972). Accordingly leaf area = k x l x w where 'k' is the crop factor (0.75) 'l' is the length and 'w' is the maximum width. Leaf area index was calculated using the formula suggested by Watson (1958).

$$LAI = \frac{\text{Total leaf area}}{\text{Land area}}$$

3.11.3.7 Chlorophyll content

The a, b and total chlorophyll content were estimated from the fully opened second leaf from the top at the panicle emergence stage by the method suggested by Arnon (1949) and expressed in mg g^{-1} fresh weight of leaf.

3.11.3.8 Proline content

Proline content was estimated from the fully opened second leaf from the top at the panicle emergence stage by the technique suggested by Bates *et al.* (1973) and expressed in mg g^{-1} fresh weight.

3.11.3.9 Relative water content (RWC)

The method proposed by Weatherly (1950), which was later modified and described in detail by Slatyer and Barrs (1965) was used to determine RWC. It was calculated as

$$RWC = \frac{\text{Fresh weight} - \text{dry weight}}{\text{Turgid weight} - \text{dry weight}} \times 100$$

3.11.4 Root characters

3.11.4.1 Root length

At harvest stage five plants were taken out carefully after a thorough irrigation and their root lengths were measured and the mean value was calculated, and recorded in cm.

3.11.4.2 Root weight

Five plants were picked out at harvest stage, their roots were separated cleaned, dried and weighed. The mean value was calculated, and expressed in g.

3.11.4.3 Root shoot ratio

Ratio of weight of dried roots and shoots of five plants were taken and the mean value was calculated.

3.11.5 Pest and disease resistance

3.11.5.1 Incidence of pests

Stem borer (*Scirpophaga incertulas*) and leaf roller (*Cnaphalocrocis medinalis*) attack were mainly found. For assessing the stem borer attack, the number of damaged tillers and the total number of tillers in each observational unit of 1 x 0.5 m selected at random were recorded and the percentage incidence was calculated as number of damaged tillers in the sample area x 100 / total number of tillers. For scoring leaf roller attack, twenty hills were selected at random and the total number of leaves and the number of leaves damaged by the pest were counted. Then the percentage of infested leaves were calculated from the data.

3.12 Benefit - cost ratio

The economics of cultivation for the field experiment was worked out considering the total cost of cultivation and the prevailing market price of the produce.

$$\text{Benefit - cost ratio} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

Two benefit-cost ratios were calculated

Actual - By using sodium silicate as the source of silica (@ Rs. 44 per kg) sodium carbonate as the source of sodium (@ Rs. 65 per kg)

Revised - By using some cheaper source of silica (@ Rs. 5 per kg)

3.13 Statistical analysis

Data relating to each character was analysed by applying the analysis of variance technique (ANOVA) as suggested by Panse and Sukhatme (1985), after appropriate transformation wherever needed. Important correlation coefficients were estimated.

RESULTS

4. RESULTS

The present investigation was conducted to study the response of four rice cultivars viz., Swarnaprabha, A4-4-2, A4-1-3 and Matta Triveni under three levels of solar radiation and two levels of silica in upland situation. The data were subjected to statistical scrutiny and results were presented in tables. A brief description of result is presented in this chapter.

4.1 Height of the plant

Result of this study revealed significant influence of solar radiation on plant height (Tables 1,2 and 3). At 30 DAS the height increased significantly from 35.3 cm to 39.7 cm with the increase in shade level from 0 to 20 per cent but the effect was on par at 20 and 40 per cent shade levels. At all the three growth stages, lowest plant height was recorded at 0 per cent shade.

A differential effect of silica on plant height was recorded at three growth stages. At harvest silica application showed a significant increase in height. While, a significant reduction in height (40.5 to 37.8 cm) was observed at 30 DAS. But the change in height with the addition of silica at 60 DAS was not significant.

Among all the four varieties tried Swarnaprabha recorded maximum height of 108.7 cm and A4-4-2 recorded the minimum height of 83.2cm

L x V interaction was found significant. At 30 DAS, L_2V_1 recorded the maximum height (48 cm) and L_0V_4 registered the minimum height (31.2 cm).

Table 1 Influence of solar radiation and silica on height (cm) of rice cultivars (30 DAS)

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	43.7	41.0	42.4	42.0	46.0	44.0	50.7	45.3	48.0	45.5	44.1	44.8
A4-4-2 (V_2)	35.3	31.0	33.2	40.3	31.7	36.0	40.7	39.3	40.0	38.8	34.0	36.4
A4-1-3 (V_3)	33.3	36.0	34.7	42.3	39.0	40.7	39.7	44.0	41.9	38.4	39.7	39.1
Matta Triveni (V_4)	33.7	28.7	31.2	42.3	34.0	38.2	42.0	37.3	39.7	39.3	33.3	36.3
Mean (L S)	36.5	34.2		41.7	37.7		43.3	41.5				
Mean (L)			35.3			39.7			42.4			
Mean (S)										40.5	37.8	

	L	S	V	LV	SV	LS	LSV
SE	0.87	0.67	0.95	1.64	1.34	1.15	2.32
CD (0.05)	3.43	2.10	2.70	4.68	3.82	3.64	6.61

Table 2 Influence of solar radiation and silica on height (cm) of rice cultivars (60 DAS)

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (v)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	66.7	70.0	68.4	83.7	104.7	94.2	94.0	94.7	94.4	81.5	89.8	85.6
A4-4-2 (V_2)	54.0	58.3	56.2	83.7	75.0	79.4	76.3	73.3	74.8	71.3	68.9	70.1
A4-1-3 (V_3)	64.3	66.0	65.2	94.0	91.3	92.7	80.0	87.7	83.9	79.4	81.7	80.6
Matta Triveni (V_4)	55.0	55.7	55.4	108.7	76.3	92.5	88.0	73.7	80.9	83.9	68.6	76.2
Mean (L S)	60.0	62.5		92.5	86.8		84.6	82.4				
Mean (L)			61.3			89.7			83.5			
Mean (S)										79.0	77.2	

	L	S	V	LV	SV	LS	LSV
SE	1.13	1.02	1.98	3.40	2.80	1.76	4.86
CD (0.05)	4.45	NS	5.65	9.79	7.99	5.54	13.84

Table 3 Influence of solar radiation and silica on height (cm) of rice cultivars (at harvest)

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	93.3	100.7	97.0	120.3	118.0	119.2	109.3	110.7	110.0	107.6	109.8	108.7
A4-4-2 (V_2)	66.7	72.3	69.5	95.0	95.0	95.0	81.7	88.3	85.0	81.1	85.2	83.2
A4-1-3 (V_3)	76.0	103.3	89.7	117.7	102.3	110.0	96.3	92.3	94.3	96.7	99.3	98.0
Matta Triveni (V_4)	69.0	74.0	71.5	112.7	115.7	114.2	101.0	94.3	97.7	94.2	94.7	94.5
Mean (L S)	76.3	87.6		111.4	107.8		97.1	96.4				
Mean (L)			81.9			109.6			96.7			
Mean (S)										94.9	97.2	

	L	S	V	LV	SV	LS	LSV
SE	1.31	0.83	1.72	2.97	2.43	1.44	4.21
CD (0.05)	5.14	2.21	4.89	8.47	6.92	4.52	11.98

Same trend was observed at 60 DAS. At harvest L_1V_1 recorded the maximum height and L_0V_2 recorded the minimum height.

In S x V interaction, at 30 DAS no significant difference was observed in Swarnaprabha and A4-1-3 with the addition of silica. But A4-4-2 and Matta Triveni showed a significant reduction in plant height. At 60 DAS significant difference was not observed in A4-4-2 and A4-1-3 with the addition of silica. At harvest all the four varieties failed to show any significant response to the addition of silica.

At 60 DAS no significant difference was noticed at 0 and 40 per cent shade with the addition of silica but a significant decrease was observed in 20 per cent shade. At harvest 20 and 40 per cent shade levels showed no response to silica addition but at 0 per cent shade a significant increase was observed.

4.2 Number of Tillers

Tillering was profoundly influenced by solar radiation at 30 DAS, 60 DAS and at harvest (Table4, 5 and 6). At 30 DAS maximum number of tillers (5.2) was recorded at 20 per cent shade. The effect of other two shade levels was on par. At 6 0 DAS a significant decrease in the tiller number was noticed with the successive increase in shade (from 8.9 to 4.8). At the harvest stage 0 and 20 per cent shade levels were on par and were significantly superior to 40 per cent shade.

With the addition of silica a significant increase was observed in tillering at 60 DAS (6.7 to 7.3) but a significant reduction was observed at 30

Table 4 Influence of solar radiation and silica on number of tillers per hill of rice cultivars (30 DAS)

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	5.7	4.7	5.2	6.0	4.7	5.4	4.7	3.7	4.2	5.5	4.4	4.9
A4-4-2 (V_2)	5.3	4.0	4.7	5.3	3.7	4.5	4.7	4.7	4.7	5.1	4.1	4.6
A4-1-3 (V_3)	4.3	4.0	4.2	5.3	5.3	5.3	4.7	5.0	4.9	4.8	4.8	4.8
Matta Triveni (V_4)	5.7	3.3	4.5	6.3	4.7	5.5	5.3	4.7	5.0	5.8	4.2	5.0
Mean (L S)	5.3	4.0		5.7	4.6		4.9	4.5				
Mean (L)			4.6			5.2			4.7			
Mean (S)										5.3	4.4	

	L	S	V	LV	SV	LS	LSV
SE	0.12	0.18	0.21	0.37	0.32	0.31	3.52
CD (0.05)	0.46	0.56	NS	1.04	0.85	0.97	1.48

Table 5 Influence of solar radiation and silica on number of tillers per hill of rice cultivars (60 DAS)

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (v)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	9.0	9.0	9.0	6.7	7.3	7.0	4.0	4.0	4.0	6.6	6.8	6.7
A4-4-2 (V_2)	8.7	9.0	8.9	6.7	8.3	7.5	5.0	5.3	5.2	6.8	7.5	7.2
A4-1-3 (V_3)	7.0	9.7	8.4	6.3	8.0	7.2	4.3	5.7	5.0	5.9	7.8	6.8
Matta Triveni (V_4)	9.3	9.0	9.2	7.3	7.0	7.2	5.0	5.3	5.2	7.2	7.1	7.2
Mean (L S)	8.5	9.2		6.8	7.7		4.6	5.1				
Mean (L)			8.8			7.2			4.8			
Mean (S)										6.6	7.3	

	L	S	V	LV	SV	LS	LSV
SE	1.16	0.22	0.26	0.45	0.37	0.38	0.64
CD (0.05)	0.62	0.70	NS	1.29	1.05	1.21	1.82

Table 6 Influence of solar radiation and silica on number of tillers per hill of rice cultivars (at harvest)

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	7.3	7.7	7.5	5.7	5.3	5.5	4.0	4.3	4.2	5.7	5.8	5.7
A4-4-2 (V_2)	7.7	8.0	7.9	5.3	6.7	6.0	4.3	5.7	5.0	5.8	6.8	6.3
A4-1-3 (V_3)	6.0	8.0	7.0	6.7	6.0	6.4	3.3	4.7	4.0	5.3	6.2	5.8
Matta Triveni (V_4)	6.3	7.0	6.7	9.0	6.3	7.7	5.7	5.3	5.5	7.0	6.2	6.6
Mean (L S)	6.8	7.7		6.7	6.1		4.3	5.0				
Mean (L)			7.3			6.4			4.7			
Mean (S)										5.9	6.3	

	L	S	V	LV	SV	LS	LSV
SE	0.38	0.27	0.30	0.52	0.43	0.47	0.74
CD (0.05)	1.51	NS	NS	1.48	1.21	1.48	2.10

DAS. Silica application revealed no significant difference in tillering at harvest.

A significant difference among varieties in tiller number was recorded only at harvest stage. A4-4-2, A4-1-3 and Matta Triveni behaved similarly and Swarnaprabha was inferior to the above three varieties.

In L x V interaction at 30 DAS, L_2V_4 recorded the maximum tillers (5.5) which was on par with all other treatments except L_0V_3 and L_2V_1. At harvest the tiller number decreased significantly from 7.3 to 4.7 with the increase in shade levels.

In S x V interaction at 30 DAS, all varieties except A 4-1-3 showed a significant reduction in tiller production with the addition of silica. At 60 DAS A4 -1-3 showed an increasing tendency and no significant response was observed in all the other three varieties with the addition of silica. At harvest no significant difference was noticed in all the four varieties with the addition of silica.

In L x S interaction, at harvest stage and at 60 DAS plants showed no significant response with the addition of silica in all the three shade levels. But at 30 DAS at 0 per cent and 20 per cent shade levels, silica application showed a significant decrease in tillering. Tiller number decreased from 5.5 to 4.0 and 4.9 to 4.5 respectively.

4.3 Dry matter production

Dry matter production was significantly influenced by solar radiation at 30 DAS, 60 DAS and at harvest (Table 7, 8 and 9).

At 60 DAS and at harvest, DMP decreased significantly with the increase in shade levels but at 30 DAS, 20 and 40 per cent shade levels were on par and 0 per cent shade was found superior (625 kg ha^{-1}).

Silica application decreased the DMP at 30 DAS and no significant response was observed at 60 DAS and at harvest.

At 30 DAS, maximum DMP was recorded by L_0V_1 (699 Kg ha^{-1}) which was on par with L_0 V_2, L_0 V_3 and L_0V_4. The minimum value was recorded by L_2V_2 (272 Kg ha^{-1}) which was on par with L_2 V_1 and L_1 V_2 (Table 7).

At 60 DAS, there was no significant variation among varieties at 0 and 40 per cent shade. But at 20 per cent shade the highest DMP was recorded by Matta Triveni (3154 Kg ha^{-1}) which was on par with Swarnaprabha and A4-4-2 and was significantly superior to A4-1-3 (Table 8).

At harvest stage also there was no significant difference among varieties at 0 and 40 per cent shade. In 20 per cent shade Swarnaprabha recorded the highest value (516 kg ha^{-1}), which was on par with A4-4-2 and A4-1-3.and was significantly superior to Matta Triveni.

A significant influence on DMP with the addition of silica was observed only at 0 per cent shade at 30 DAS but in all other treatments silica addition had no influence on DMP.

Table 7 Influence of solar radiation and silica on drymatter production (kg ha^{-1}) of rice cultivars (30 DAS)

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	641	756	699	590	442	516	346	282	314	526	493	510
A4-4-2 (V_2)	794	378	586	314	274	294	301	244	273	470	299	384
A4-1-3 (V_3)	692	378	535	404	372	388	333	449	391	476	400	438
Matta Triveni (V_4)	821	538	680	436	449	443	462	333	398	573	440	507
Mean (L S)	737	513		436	384		361	327				
Mean (L)			625			410			344			
Mean (S)										511	408	

	L	S	V	LV	SV	LS	LSV
SE	23.30	25.63	35.13	60.85	49.68	44.40	86.05
CD (0.05)	91.47	80.76	100.11	173.39	141.57	139.88	245.21

Table 8 Influence of solar radiation and silica on drymatter production (kg ha^{-1})of rice cultivars (60 DAS)

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	3526	3282	3404	2833	1923	2378	1385	1051	1218	2581	2085	2333
A4-4-2 (V_2)	3308	3340	3324	2628	2295	2462	1218	962	1090	2385	2199	2292
A4-1-3 (V_3)	2833	2353	2593	2167	2282	2225	949	1500	1225	1983	2045	2014
Matta Triveni (V_4)	2744	3231	2988	3564	2744	3154	1910	1051	1481	2739	2342	2541
Mean (L S)	3103	3052		2798	2311		1365	1141				
Mean (L)			3077			2555			1253			
Mean (S)										2422	2168	

	L	S	V	LV	SV	LS	LSV
SE	130.63	146.60	173.34	300.23	245.13	253.92	424.58
CD (0.05)	512.83	NS	493.94	855.54	698.54	800.08	1209.91

4.4 Culm Strength

Solar radiation had influenced the culm strength significantly. Culm strength decreased from 35.10 mg cm^{-1} to 18.29 mg cm^{-1} with the advancement of shade levels from 0 to 40 per cent (Table 10).

Silica application failed to give any significant result on culm strength but an increasing trend was observed.

Among varieties A4-1-3 registered the maximum culm strength of 28.15 mg cm^{-1} which was on par with Swarnaprabha and Matta Triveni.

There was no significant difference in culm strength among varieties in all the three shade levels.

In Swarnaprabha culm strength increased significantly with the addition of silica. A4-4-2 and Matta Triveni failed to give any response to silica application. A significant reduction in culm strength was observed in A 4-1-3 with the application of silica.

No significant change was seen in culm strength at 20 and 40 per cent shade levels with the addition of silica but at 0 per cent shade level application of silica decreased the culm strength significantly.

4.5 Length of panicle

Panicle length was significantly influenced by solar radiation. The panicle length was maximum (23.21 cm) at 20 per cent shade and was on par

Table 10 Influence of solar radiation and silica on culm strength (mg cm^{-1}) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	27.97	40.30	34.14	25.01	27.60	26.31	17.00	17.97	17.49	23.33	28.62	25.98
A4-4-2 (V_2)	33.45	33.60	33.53	26.90	25.39	26.15	19.01	15.41	17.21	26.45	24.80	25.63
A4-1-3 (V_3)	39.10	34.30	36.70	32.35	25.90	29.13	19.03	18.24	18.64	30.16	26.15	28.15
Matta Triveni (V_4)	31.97	40.07	36.02	27.20	27.00	27.10	20.47	19.17	19.82	26.55	28.75	27.65
Mean (L S)	33.12	37.07		27.87	26.47		18.88	17.70				
Mean (L)			35.10			27.17			18.29			
Mean (S)										26.62	27.08	

	L	S	V	LV	SV	LS	LSV
SE	0.90	0.64	0.83	1.43	1.17	1.11	2.03
CD (0.05)	3.51	NS	2.36	4.08	3.33	3.50	5.77

with zero per cent shade. Minimum length (21.5 cm) was recorded at 40 per cent shade level (Table 11).

No significant difference was seen in panicle length with the addition of silica.

Among the four varieties tried Swarnaprabha recorded the longest panicle (22.9 cm) and was on par with A4-4-2 and Matta Triveni. The shortest panicle was observed in A4-1-3 (21.8 cm).

In L x V interaction cultivar A4-1-3 recorded the lowest value both at 0 and 20 per cent shade levels. The other three varieties behaved similarly. At 40 per cent shade level no significant difference was seen among varieties. All the varieties showed no significant difference with the increase of shade level from 0 to 20 per cent. Panicle length decreased in cultivars Swarnaprabha and A4-4-2 when the shade increased from 20 to 40 per cent; but no significant difference was seen in the other two varieties.

There was no significant difference in all the four varieties with the addition of silica. Swarnaprabha recorded the maximum panicle length (22.9 cm) and was on par with A4-4-2 and Matta Triveni in the absence of silica. Cultivar A4-1-3 recorded the lowest length (21.1 cm). In the presence of silica all the cultivars behaved similarly with respect to panicle length.

Silica addition had little effect on length of panicle at all the three shade levels. No significant difference was seen among shade levels in silica added treatments. In the absence of silica 20 per cent shade was superior

Table 11 Influence of solar radiation and silica on length of panicle (cm) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	23.7	22.2	23.0	24.1	24.4	24.3	20.8	22.1	21.4	22.9	22.9	22.9
A4-4-2 (V_2)	21.8	23.3	22.6	23.4	23.9	23.7	21.6	21.2	21.4	22.3	22.8	22.5
A4-1-3 (V_3)	21.5	23.1	22.3	21.9	22.1	22.0	19.9	22.4	21.2	21.1	22.5	21.8
Matta Triveni (V_4)	21.9	23.3	22.6	22.9	22.9	22.9	21.5	22.8	22.2	22.1	23.0	22.6
Mean (L S)	22.2	23.0		23.1	23.3		21.0	22.1				
Mean (L)			22.6			23.2			21.5			
Mean (S)										22.1	22.8	

	L	S	V	LV	SV	LS	LSV
SE	0.31	0.29	0.36	0.63	0.51	0.51	0.99
CD (0.05)	1.21	NS	1.03	1.79	1.46	1.60	2.53

(23.1 cm) to 40 per cent shade, (21 cm) and the former was on par with zero per cent shade.

4.6 Weight of panicle

The panicle weight was statistically on par at 0 and 20 per cent shade levels (2.66 g and 2.53 g respectively). The lowest weight (1.83g) was recorded at 40 per cent shade (Table 12).

Silica application significantly increased the panicle weight from 2.23 to 2.45 g.

There was no significant difference in panicle weight among all the four varieties tried.

There was no significant difference among varieties both at 0 per cent and 20 per cent shade. A4-1-3 recorded the highest value (2.78 g) at 20 per cent shade, and was on par with Swarnaprabha (2.66). Only Matta Triveni showed a decrease in panicle weight (from 2.77 to 2.35 g) when the shade increased from 0 to 20 per cent shade. Except A4-4-2, in all the other varieties panicle weight decreased significantly with the advancement of shade level from 20 to 40 per cent.

Both in the presence and absence of silica all the varieties behaved similarly. In cultivar Matta Triveni silica application increased the panicle weight significantly.

In the absence of silica, 0 per cent and 20 per cent shade behaved similarly (2.50g and 2.58 g), but 40 per cent shade recorded the lowest value

Table 12 Influence of solar radiation and silica on weight of panicle (g panicle^{-1}) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	2.48	2.65	2.57	2.79	2.52	2.66	1.53	2.12	1.83	2.27	2.43	2.35
A4-4-2 (V_2)	2.39	2.78	2.59	2.37	2.28	2.33	1.74	2.23	1.99	2.17	2.43	2.30
A4-1-3 (V_3)	2.71	2.70	2.71	2.89	2.67	2.78	1.59	1.86	1.73	2.40	2.41	2.40
Matta Triveni (V_4)	2.41	3.13	2.77	2.27	2.42	2.35	1.61	1.99	1.80	2.10	2.51	2.31
Mean (L S)	2.50	2.82		2.58	2.47		1.62	2.05				
Mean (L)			2.66			2.53			1.83			
Mean (S)										2.23	2.45	

	L	S	V	LV	SV	LS	LSV
SE	0.07	0.06	0.08	0.14	0.12	0.10	0.20
CD (0.05)	0.28	0.18	NS	0.41	0.34	0.31	0.58

(1.62 g). In the presence of silica, 0 per cent shade was superior to other two shade levels (2.82g). A significant increase in panicle weight was seen in 0 per cent and 40 per cent shade with the addition of silica.

4.7 Number of productive tillers per hill

Solar radiation influenced the production of productive tillers significantly. Maximum number of productive tillers was recorded in the open situation (6.2) which was on par with 20 per cent shade (5.5). Lowest number of productive tillers was recorded at 40 per cent shade (3.2) (Table 13).

There was no significant difference in the number of productive tillers with the addition of silica.

Among varieties Matta Triveni recorded maximum Number of productive tillers (5.6), which was on par with A4-4-2.

L x V interactions revealed no significant difference between A4-1-3 and Matta Triveni at 0 and 20 per cent shade levels, but a significant decrease was seen in Swarnaprabha and A 4-4-2 when the shade level increased from 0 to 20 per cent. A significant reduction in the number of productive tillers was noticed in all the four varieties with the increase in shade level from 20 to 40 per cent

All the four varieties failed to give any significant response to silica application.

L x S interaction revealed that in the absence and presence of silica all the intensities of shade behaved similarly. In the absence of silica 0 and 20

Table 13 Influence of solar radiation and silica on number of productive tillers per hill of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	6.3	6.3	6.3	5.3	4.0	4.7	2.3	3.0	2.7	4.6	4.4	4.5
A4-4-2 (V_2)	6.7	6.7	6.7	5.0	5.3	5.2	3.0	3.0	3.0	4.9	5.0	5.0
A4-1-3 (V_3)	5.3	6.3	5.8	5.7	6.0	5.9	2.3	3.0	2.7	4.4	5.1	4.8
Matta Triveni (V_4)	5.7	6.0	5.9	7.7	5.3	6.5	4.7	4.3	4.5	6.0	5.2	5.6
Mean (L S)	6.0	6.3		5.9	5.2		3.1	3.3				
Mean (L)			6.2			5.5			3.2			
Mean (S)										5.0	4.9	

	L	S	V	LV	SV	LS	LSV
SE	0.39	0.24	0.24	0.42	0.34	0.42	0.59
CD (0.05)	1.52	NS	0.69	1.19	0.98	1.32	1.69

per cent shade levels recorded more productive tillers (6.0 and 5.9 respectively) than at 40 per cent shade (3.1).

4.8 Number of spikelets per panicle

Solar radiation influenced the spikelets production significantly. Number of spikelets per panicle decreased significantly with the increase in shade level to 40 per cent (Table 14). The number of spikelets per panicle were on par at 0 and 20 per cent shade (120 and 118 respectively), but at 40 per cent shade it decreased significantly (97).

There was no significant change in the number of spikelets per panicle with the addition of silica.

No significant difference was found among the four varieties in the number of spikelets produced.

Variety and shade interaction revealed no significant difference between varieties at 0 and 40 per cent shade levels. But at 20 per cent shade, Swarnaprabha recorded the highest spikelet number (128) which was on par with A 4-4-2 and A 4- 1-3.

In the interaction between silica and varieties only Matta Triveni showed a significant increase in the spikelet number (103.5 to 119.0) with the addition of silica.

An increase in spikelet number was observed at 0 and 40 per cent shade levels with the addition of silica but at 20 per cent shade no response was observed.

Table 14 Influence of solar radiation and silica on number of spikelets per panicle of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	121.0	125.0	123.0	127.7	128.3	128.0	82.7	112.7	97.7	110.5	122.0	116.2
A4-4-2 (V_2)	102.0	127.0	114.5	114.0	119.7	116.9	91.3	98.3	94.8	102.4	115.0	108.7
A4-1-3 (V_3)	120.6	117.3	119.0	124.3	118.7	121.5	89.7	94.6	92.2	111.5	110.2	110.9
Matta Triveni (V_4)	112.7	136.3	124.5	104.3	108.3	106.3	93.6	112.3	103.0	103.5	119.0	111.3
Mean (L S)	114.1	126.4		117.6	118.8		89.3	104.5				
Mean (L)			120.2			118.2			96.9			
Mean (S)										107.0	116.5	

	L	S	V	LV	SV	LS	LSV
SE	1.49	1.61	3.45	5.97	4.88	2.79	8.45
CD (0.05)	5.84	5.02	NS	17.02	13.89	8.80	22.06

4.9 Number of filled grains per panicle

Effect of solar radiation, silica and cultivars on the number of filled grains produced was recorded in Table15. Shade levels registered no significant influence on the number of filled grains per panicle.

A significant increase in grain production (from 81.8 to 90.4) was observed with the addition of silica.

There was no significant difference among varieties in grain production.

L x V interaction revealed that only Matta Triveni showed a significant reduction in grain production with increase in shade levels. Filled grains per panicle decreased from 107 to 84 and to 71 with the increasing shade level from 0 to 20 and 40 per cent respectively.

A significant increase in grain production (77.0 to 97.5) was seen only in Matta Triveni with the addition of silica.

L x S interaction revealed that no significant difference in filled grains production at 20 per cent shade with the addition of silica. But at 0 and 40 per cent shade it showed a significant increase (91 to 104 and 66 to 75 respectively).

4.10 Thousand grain weight

The mean values of thousand grain weight were documented in Table 16. No significant difference in thousand grain weight was obtained with the

Table15 Influence of solar radiation and silica on number of filled grains per panicle of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	92.7	98.3	95.5	97.7	88.3	93.0	65.7	83.0	74.4	85.4	89.9	87.6
A4-4-2 (V_2)	85.7	103.0	94.4	80.3	89.7	85.0	69.7	66.0	67.9	78.6	86.2	82.4
A4-1-3 (V_3)	96.0	92.0	94.0	98.3	100.7	99.5	64.7	71.7	68.2	86.3	88.1	87.2
Matta Triveni (V_4)	90.0	123.3	106.7	79.0	89.0	84.0	62.0	80.3	71.2	77.0	97.5	87.3
Mean (L S)	91.1	104.2		88.8	91.9		65.5	75.3				
Mean (L)			97.6			90.4			70.4			
Mean (S)										81.8	90.4	

	L	S	V	LV	SV	LS	LSV
SE	1.74	1.73	2.71	4.69	3.83	3.00	6.63
CD (0.05)	6.83	5.45	NS	13.36	10.91	9.44	18.89

Table 16 Influence of solar radiation and silica on thousand grain weight (kg ha^{-1}) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	23.87	25.20	24.54	25.33	24.10	24.72	21.67	22.03	21.85	23.62	23.78	23.70
A4-4-2 (V_2)	25.33	24.60	24.97	25.53	24.17	24.85	21.20	22.03	21.62	24.02	23.60	23.81
A4-1-3 (V_3)	25.30	26.30	25.80	26.23	24.37	25.30	23.70	22.70	23.20	25.08	24.46	24.77
Matta Triveni (V_4)	23.17	23.53	23.35	24.97	24.10	24.54	21.40	21.50	21.45	23.18	23.04	23.11
Mean (L S)	24.42	24.91		25.52	24.19		21.99	22.07				
Mean (L)			24.66			24.85			22.03			
Mean (S)										23.98	23.72	

	L	S	V	LV	SV	LS	LSV
SE	0.31	0.30	0.37	0.64	0.52	0.52	0.90
CD (0.05)	1.22	NS	1.05	1.81	1.48	1.65	2.56

increase of shade from 0 to 20 per cent. A significant reduction was seen in 40 per cent shade compared to other shade levels.

Silica addition recorded no significant difference in thousand grain weight.

Among varieties A4-1-3 recorded the highest value (24.78 g), which was significantly different from the other three varieties. Matta Triveni had the lowest value (23.11 g) and was on par with Swarnaprabha and A 4-4-2.

Significant difference was seen in shade and variety interaction. In all the four varieties grain weight reduced significantly as the shade increased from 20 to 40 per cent. But no significant difference was seen in varieties when shade increased from 0 to 20 per cent.

In S x V interaction only A4-4-2 showed a significant reduction in grain weight (24.02 to 23.60 g).

Addition of silica showed a significant reduction (25.52 to 24.19 g) in grain weight only in 20 per cent shade.

4.11 Chaff percentage

Chaff production was significantly influenced by solar radiation. Data presented in table 17 showed that chaff per cent increased from 22 to 30 with the increase in shade from 0 to 40 per cent.

A significant reduction (26 to 24) in chaff percentage was recorded with the addition of silica.

Table 17 Influence of solar radiation and silica on chaff percentage (per cent) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	28.17	30.43	29.30	23.53	30.50	27.02	36.10	29.50	32.80	29.27	30.14	29.71
A4-4-2 (V_2)	15.77	14.20	14.99	36.10	24.53	30.32	30.87	27.67	29.27	27.58	22.13	24.86
A4-1-3 (V_3)	20.07	20.83	20.45	20.30	14.90	17.60	22.53	24.67	23.60	20.97	20.13	20.55
Matta Triveni (V_4)	25.20	19.37	22.29	24.30	19.80	22.05	30.43	29.37	29.90	26.64	22.85	24.75
Mean (L S)	22.30	21.21		26.06	22.43		29.98	27.80				
Mean (L)			21.76			24.25			28.89			
Mean (S)										26.11	23.81	

	L	S	V	LV	SV	LS	LSV
SE	0.51	0.59	1.14	1.97	1.61	1.02	2.79
CD (0.05)	2.02	1.86	3.24	5.61	4.58	3.21	7.94

The lowest percentage of chaff was seen in A4-1-3 (21) and was on par with Matta Triveni. Highest chaff percentage was recorded in Swarnaprabha (30).

Shade and variety interaction revealed that A4-4-2 recorded lowest chaff percentage (15) at 0 per cent shade level and was on par with $L_O V_3$ and $L_I V_3$. Swarnaprabha registered the highest chaff percentage (30). At 20 per cent shade level A4-4-2 recorded the highest chaff percentage and A4-1-3 recorded the lowest value (30.32 and 17.6 respectively). A4-1-3 recorded the lowest value at 40 per cent (23.6 per cent) shade. Swarnaprabha registered the highest value of 32.8 per cent, and was on par with A4-4-2 and Matta Triveni at this shade level.

In S x V interaction a significant reduction in chaff percentage was shown only by A4-4-2 (27. 58 to 22.13) with the addition of silica.

L x S interaction revealed that silica application significantly reduced the chaff percentage with the increase in shade level from 0 to 20 per cent but no significant reduction was seen at 40 per cent shade.

4.12 Grain yield

Effect of shade on grain yield was found significant (Table 18). Maximum grain yield of 2764 kg ha^{-1} was observed in open situation and it decreased significantly to 1641 kg ha^{-1} at 20 per cent shade and to 568 kg ha^{-1} at 40 per cent shade

Table 18 Influence of solar radiation and silica on grain yield (kg ha^{-1}) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	2541	2780	2660	1179	1797	1488	469	440	455	1396	1672	1534
A4-4-2 (V_2)	2774	3324	3049	1382	2196	1789	471	610	541	1542	2043	1793
A4-1-3 (V_3)	2626	2740	2683	1247	1796	1522	512	668	590	1462	1735	1598
Matta Triveni (V_4)	2593	2731	2662	1461	2070	1766	691	684	688	1582	1828	1705
Mean (L S)	2633	2894		1317	1965		536	601				
Mean (L)			2763			1641			568			
Mean (S)										1495	1820	

	L	S	V	LV	SV	LS	LSV
SE	27.24	34.82	55.65	96.38	79.69	60.32	136.30
CD (0.05)	106.95	109.72	158.57	274.65	224.55	190.05	388.41

Addition of silica increased the yield significantly. The yield realized at 100 kg SiO_2 ha^{-1} was 1820 kg ha^{-1}, and was significantly superior to yield obtained (1495 Kg ha^{-1}) with out the application of silica.

Among varieties Matta Triveni and A4-4-2 behaved similarly but were superior to Swarnaprabha and A 4-1-3. A4-4-2 and Matta Triveni recorded an yield of about 1.7 t ha^{-1} while the other two varieties recorded an yield potentiality of 1.5 t ha^{-1}.

L x V interaction showed a significant difference among mean values. At 0 per cent shade A4-4-2 performed better with a yield potential of 3049 kg ha^{-1} and was significantly superior to all the other varieties. At 20 per cent shade also this superiority was maintained. But at this level of shade A4-4-2 behaved similarly to Matta Triveni.

Better response to silica application was shown by A4-4-2 (1542 to 2043 kg ha^{-1}). In the presence of silica, A4-4-2 and Matta Triveni behaved similarly (2043 and 1828 kg ha^{-1}) but the former was superior to the other two varieties.

The mean value of L x S interaction revealed that at 0 and 20 per cent shade levels addition of silica recorded significantly higher yield (2763 and 1641 respectively), but at 40 per cent shade silica addition failed to retain that response.

4.13 Straw yield

Solar radiation influenced the straw yield significantly. Straw yield recorded at lower two levels of shade were on par but was significantly superior to 40 per cent shade. Highest straw yield of 4585 kg ha^{-1} was recorded at 20 per cent shade and lowest straw yield of 2481 kg ha^{-1} was observed at 40 per cent shade (Table 19).

Silica application significantly increased the straw yield. Addition of silica recorded 4034 kg ha^{-1} of straw yield.

Among varieties Swarnaprabha recorded the maximum straw yield of 4336 kg ha^{-1}, which was significantly superior to all other varieties.

Straw yield differed significantly in L x V interaction. At 20 and 40 per cent shade levels all varieties behaved similarly. At 0 per cent shade Swarnaprabha recorded the maximum straw yield of 5734 kg ha^{-1} and was significantly superior to other varieties. Among varieties, A4-4-2 and Matta Triveni registered an increase in straw yield(4485 and 4780 kg ha^{-1} respectively) as the shade advanced from 0 to 20 per cent but a reduction was observed in Swarnaprabha. In S x V interaction response to silica application was shown only by Swarnaprabha (3762 to 4815 kg ha^{-1}).

In L x S interaction a significant increase (4097 to 5073 kg ha^{-1}) in yield was seen only in 20 per cent shade with the addition of silica.

Table 19 Influence of solar radiation and silica on straw yield (kg ha^{-1}) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	5004	6466	5735	3918	5617	4768	2649	2649	2649	3857	4911	4384
A4-4-2 (V_2)	2763	3324	3044	4261	4709	4485	2675	2675	2675	3233	3569	3401
A4-1-3 (V_3)	4564	3829	4197	3766	4851	4309	2788	2788	2788	3706	3823	3764
Matta Triveni (V_4)	3303	3605	3454	4443	5116	4780	2781	2781	2781	3509	3834	3672
Mean (L S)	3909	4306		4097	5073		2723	2723				
Mean (L)			4107			4585			2723			
Mean (S)										3576	4034	

	L	S	V	LV	SV	LS	LSV
SE	156.17	158.52	170.29	290.95	240.82	274.57	417.11
CD (0.05)	613.11	499.48	485.26	840.49	686.26	865.12	11188.63

4.14 Harvest Index

There was no significant reduction in HI with the increase of shade level from 0 per cent to 20 per cent (Table20). Significantly lower value was recorded in 40 per cent shade (0.222).

Silica application increased the HI significantly from 0.250 to 0.311.

Among cultivars highest HI was seen in A4-4-2 (0.302), which was on par with A4-1-3 and Matta Triveni. Swarnaprabha recorded the lowest value.

In Lx V interaction a significant difference was shown only by variety Matta Triveni, where HI increased from 0.292 to 0.364 when the shade level increased from 0 to 20 per cent. HI decreased significantly in varieties Swarnaprabha, A4-4-2, and A4-1-3. The lowest HI in 20 and 40 per cent shade level was recorded by Swarnaprabha (0.243 and 0.154 respectively). In open condition Matta Triveni recorded the lowest HI (0.292).

There was an increase in HI in cultivars A4-4-2 and A4-1-3 with the addition of silica. No significant response was noticed in Swarnaprabha and Matta Triveni.

Silica addition helped to increase the HI at 20 per cent shade (0.244 to 0.371). No significant response was seen at 0 and 40 per cent shade.

4.15 Crop growth Rate

Mean values of C.G.R computed between 30 and 60 DAS were furnished in the Table 21.

Table 20 Influence of solar radiation and silica on harvest index of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	0.333	0.279	0.306	0.232	0.254	0.243	0.154	0.154	0.154	0.240	0.229	0.234
A4-4-2 (V_2)	0.279	0.365	0.322	0.235	0.469	0.352	0.187	0.277	0.232	0.234	0.370	0.302
A4-1-3 (V_3)	0.324	0.326	0.325	0.220	0.323	0.272	0.212	0.333	0.273	0.252	0.327	0.290
Matta Triveni (V_4)	0.306	0.278	0.292	0.288	0.440	0.364	0.225	0.235	0.230	0.273	0.318	0.295
Mean (L S)	0.311	0.312		0.244	0.372		0.195	0.250				
Mean (L)			0.311			0.308			0.222			
Mean (S)										0.250	0.311	

	L	S	V	LV	SV	LS	LSV
SE	0.010	0.011	0.014	0.024	0.020	0.019	0.034
CD (0.05)	0.040	0.034	0.040	0.069	0.056	0.059	0.098

Table 21 Influence of solar radiation and silica on crop growth rate (g m-2 day-1) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	10.52	8.40	9.46	8.80	6.73	7.77	3.50	2.53	3.02	7.61	5.89	6.75
A4-4-2 (V_2)	8.20	9.87	9.04	7.47	7.73	7.60	3.30	2.03	2.67	6.32	6.54	6.43
A4-1-3 (V_3)	7.13	6.17	6.65	7.20	6.30	6.75	2.03	3.50	2.77	5.45	5.32	5.39
Matta Triveni (V_4)	8.43	8.97	8.70	12.87	7.63	10.25	3.67	2.44	3.06	8.32	6.35	7.34
Mean (L S)	8.57	8.35		9.09	7.10		3.13	2.63				
Mean (L)			8.46			8.09			2.88			
Mean (S)										6.93	6.03	

	L	S	V	LV	SV	LS	LSV
SE	0.22	0.16	0.27	0.47	0.38	0.28	0.66
CD (0.05)	0.88	0.51	0.77	1.34	1.09	0.88	1.89

The highest CGR value of 8.86 g m^{-2} day^{-1} was recorded at 0 per cent shade, which was on par with 20 per cent shade but was significantly superior to 40 per cent shade.

No significant difference was observed in CGR with the addition of silica.

Among the varieties Matta Triveni recorded the highest value (7.34 g m^{-2} day^{-1}), and was on par with Swarnaprabha (6.75 g m^{-2} day^{-1}).

In L x V interaction V_1 and V_2 showed a significant decrease in CGR when shade level increased from 0 to 20 per cent but V_3 and V_4 registered an increase in CGR. In all the four varieties a decrease in CGR was noticed as the shade level increased from 20 to 40 per cent.

S x V interaction showed a significant reduction of CGR in varieties V_1 and V_4 with the addition of silica.

4.16 Relative growth Rate

R.G.R was computed at 30 DAS to 60 DAS and the mean values were recorded in Table 22. The highest RGR value was obtained at 20 per cent shade (63.96 mg g^{-1} day^{-1}) and it was on par with 0 per cent shade but was significantly superior to 40 per cent shade.

Silica application failed to give any significant difference in RGR.

There was no significant difference recorded among varieties in RGR values.

Table 22 Influence of solar radiation and silica on relative growth rate (mg g-1 day-1) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	66.10	58.50	62.30	58.93	63.47	61.20	39.37	41.47	40.42	54.80	54.48	54.64
A4-4-2 (V_2)	47.40	64.03	55.72	70.83	69.97	70.40	47.20	50.10	48.65	55.14	61.37	58.26
A4-1-3 (V_3)	47.90	70.26	59.08	55.63	61.47	58.55	44.30	39.10	41.70	49.28	56.94	53.11
Matta Triveni (V_4)	47.00	64.23	55.62	70.93	60.43	65.68	38.53	37.90	38.22	52.15	54.19	53.17
Mean (L S)	52.10	64.26		64.08	63.84		42.35	42.14				
Mean (L)			58.18			63.96			42.25			
Mean (S)										52.84	56.74	

	L	S	V	LV	SV	LS	LSV
SE	1.62	1.31	1.90	3.28	2.68	2.27	4.64
CD (0.05)	6.36	NS	NS	9.35	7.64	7.16	13.23

In L x V interaction V_2 and V_4 showed an increase in RGR when the shade level increased from 0 to 20 per cent. All varieties showed a reduction in RGR at 20 and 40 per cent shade.

In S x V interaction only A4-1-3 showed a positive response to silica application. No significant difference was recorded in the varieties.

Silica and shade interaction was significant only in 0 per cent shade.

4.17 Net Assimilation Rate

NAR was computed at 30 to 60 DAS (Table 23). The values at 0 and 20 per cent shade were on par and 40 per cent shade was significantly inferior to (3.22 g cm^{-2} day^{-1}) the other two shade levels.

Both silica and varieties failed to give any significant difference on NAR.

L x V interaction revealed no significant change in NAR in the varieties as the shade increased from 0 to 20 per cent. But a significant reduction was seen in the varieties at 40 per cent shade compared to the other two solar radiation intensities.

In S x V interaction only Swarnaprabha showed a significant response silica, where a decrease was observed with the addition of silica (5.63 to 3.86 g cm^{-2} day^{-1}).

L x S interaction was not significant.

Table 23 Influence of solar radiation and silica on net assimilation rate (mg cm-2 days-1) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	6.63	5.36	6.00	6.88	3.90	5.39	3.39	2.33	2.86	5.63	3.86	4.75
A4-4-2 (V_2)	5.73	7.00	6.37	5.96	4.82	5.39	3.77	2.73	3.25	5.15	4.85	5.00
A4-1-3 (V_3)	5.21	4.46	4.84	4.93	6.06	5.50	2.29	3.90	3.10	4.14	4.81	4.48
Matta Triveni (V_4)	4.73	6.57	5.65	7.56	5.74	6.65	4.77	2.61	3.69	5.69	4.97	5.33
Mean (L S)	5.58	5.85		6.33	5.13		3.56	2.89				
Mean (L)			5.71			5.73			3.22			
Mean (S)										5.15	4.62	

	L	S	V	LV	SV	LS	LSV
SE	0.36	0.35	0.39	0.68	0.56	0.60	0.96
CD (0.05)	1.41	NS	NS	1.94	1.59	1.90	2.75

4.18 Leaf Area Index

LAI was computed at 30 DAS and 60 DAS and was recorded in Table24 and 25 respectively.

At 30 DAS, 20 and 40 per cent shade levels behaved similarly and 0 per cent shade was superior (0.961) to the other two shades. At 30 DAS 40 per cent shade level was inferior to 0 and 20 per cent shade, which were behaved similarly.

Silica addition failed to give any significant difference in LAI.

No significant difference was observed among the varieties at 30 DAS, but at 60 DAS A4-1-3 was found inferior to all other varieties, which were on par with each other.

In L x V interaction at 30 DAS all values at 20 and 40 per cent shade were on par with each other. In 0 per cent shade, A4-1-3, Swarnaprabha and Matta Triveni behaved similarly and A4-4-2 recorded the lowest value (0.895). At 60 DAS no significant differences was observed in Swarnaprabha, A4-4-2 and A4-1-3 with increase in shade from 0 to 40 per cent. A significant reduction was observed in the varieties when the shade increased from 20 to 40 per cent.

Silica and variety interaction revealed no significant difference in LAI.

No significant difference was noticed in 0, 20 and 40 per cent shade with the addition of silica in the two growth stages.

Table 24 Influence of solar radiation and silica on leaf area index of rice cultivars (30 DAS)

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	0.893	1.040	0.967	0.547	0.713	0.630	0.653	0.647	0.650	0.698	0.800	0.749
A4-4-2 (V_2)	0.907	0.883	0.895	0.533	0.710	0.622	0.463	0.590	0.527	0.634	0.728	0.681
A4-1-3 (V_3)	1.003	1.053	1.028	0.630	0.523	0.577	0.616	0.517	0.567	0.750	0.698	0.724
Matta Triveni (V_4)	0.963	0.943	0.953	0.570	0.607	0.589	0.620	0.527	0.574	0.718	0.692	0.705
Mean (L S)	0.942	0.980		0.570	0.638		0.588	0.570				
Mean (L)			0.961			0.604			0.579			
Mean (S)										0.700	0.729	

	L	S	V	LV	SV	LS	LSV
SE	0.03	0.02	0.03	0.05	0.04	0.04	0.07
CD (0.05)	0.11	NS	NS	0.13	0.11	0.11	0.19

Table 25 Influence of solar radiation and silica on leaf area index of rice cultivars (60 DAS)

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	2.07	2.26	2.17	2.01	1.94	1.98	1.50	1.67	1.59	1.86	1.96	1.91
A4-4-2 (V_2)	2.22	2.12	2.17	2.59	2.39	2.49	1.30	1.27	1.29	2.04	1.93	1.98
A4-1-3 (V_3)	1.82	1.90	1.86	1.94	1.84	1.89	1.25	1.46	1.36	1.67	1.73	1.70
Matta Triveni (V_4)	1.76	1.91	1.84	2.72	2.49	2.61	1.59	1.47	1.53	2.02	1.96	1.99
Mean (L S)	1.97	2.05		2.32	2.17		1.41	1.47				
Mean (L)			2.01			2.24			1.44			
Mean (S)										1.90	1.89	

	L	S	V	LV	SV	LS	LSV
SE	0.04	0.07	0.08	0.15	0.12	0.13	0.21
CD (0.05)	0.17	NS	0.24	0.42	0.34	0.39	0.59

4.19 Specific leaf weight

SLW was computed on two stages, Viz., 30 DAS and 60 DAS. The results were shown in the Tables 26 and 27.

The first two levels of shade behaved similarly at 30 DAS. But at 60 DAS, SLW decreased (6.15 to 5.67 mg cm^{-2}) significantly when the shade level increased from 0 to 20 per cent. A significant reduction in SLW was observed at the two growth stages when the shade level increased from 20 to 40 per cent.

SLW did not differ significantly with silica application in the two stages.

Swarnaprabha and A4-1-3 behaved similarly at 30 DAS and at harvest. At 60 DAS A4-1-3 was significantly superior to Swarnaprabha and the other two varieties recorded intermediate values and were on par with each other.

In L x V interaction at 30 DAS the higher SLW (4.87 mg cm^{-2}) was recorded by L_1V_3 which was significantly superior to all the other interactions. At 60 DAS highest SLW (6.70 mg cm^{-2}) was recorded by L_0 V_3 which was on par with L_0 V_4.

Silica and variety interaction revealed no significant influence in SLW at 60 DAS with the addition of silica. At 30 DAS, SLW decreased with the addition of silica in A4-4-2 and A4-1-3. Swarnaprabha recorded a significant increase while no response was observed in Matta Triveni.

Silica application did not give any significant difference at all the three shade levels at the two growth stages.

Table 26 Influence of solar radiation and silica on specific leaf weight (mg cm^{-2}) of rice cultivars(30 DAS)

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	5.43	4.17	4.80	4.97	4.23	4.60	4.67	4.03	4.35	5.02	4.14	4.58
A4-4-2 (V_2)	4.23	4.00	4.12	3.77	4.73	4.25	3.53	4.30	3.92	3.84	4.34	4.09
A4-1-3 (V_3)	3.93	5.00	4.47	4.53	5.20	4.87	4.23	4.17	4.20	4.23	4.79	4.51
Matta Triveni (V_4)	4.03	4.00	4.02	4.63	4.50	4.57	3.97	3.70	3.84	4.21	4.07	4.14
Mean (L S)	4.41	4.29		4.48	4.67		4.10	4.05				
Mean (L)			4.35			4.57			4.08			
Mean (S)										4.33	4.34	

	L	S	V	LV	SV	LS	LSV
SE	0.11	0.77	0.08	1.14	0.11	0.17	0.20
CD (0.05)	0.44	NS	0.23	0.40	0.32	0.37	0.56

Table 27 Influence of solar radiation and silica on specific leaf weight (mg cm^{-2}) of rice cultivars (60 DAS)

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	5.93	5.80	5.87	5.37	5.70	5.54	4.60	4.50	4.55	5.30	5.33	5.32
A4-4-2 (V_2)	5.37	5.80	5.59	5.27	5.30	5.29	5.20	5.33	5.27	5.28	5.48	5.38
A4-1-3 (V_3)	6.77	6.63	6.70	5.87	6.00	5.94	4.30	4.23	4.27	5.65	5.62	5.63
Matta Triveni (V_4)	6.60	6.30	6.45	5.60	5.43	5.52	4.53	4.17	4.35	5.58	5.30	5.44
Mean (L S)	6.17	6.13		5.53	5.61		4.66	4.56				
Mean (L)			6.15			5.57			4.61			
Mean (S)										5.45	5.43	

	L	S	V	LV	SV	LS	LSV
SE	0.08	0.09	0.09	0.16	0.13	0.15	0.23
CD (0.05)	0.33	NS	0.27	0.46	0.38	0.47	0.65

4.20 Leaf Area Duration

The highest LAD was recorded at 0 per cent shade (44.3 days), which was significantly superior to 20 and 40 per cent shade. (42.8 and 30.2 days respectively) (Table 28).

Silica addition had little effect on leaf area duration.

Among the cultivars Swarnaprabha, A4-4-2 and Matta Triveni behaved similarly, but A4-1-3 recorded significantly the lowest LAD (36.23).

In L x V interaction no significant difference in LAD was seen among cultivars. In 20 per cent shade the highest value was recorded by Matta Triveni (48 days) and was on par with A4-4-2 (46.7 days). At 40 per cent shade the lowest value was recorded by A4-4-2 (27.1 days) and all other varieties were superior to this and were on par with each other.

In S x V interaction all varieties behaved similarly in the absence of silica. But in the presence of silica Swarnaprabha recorded the highest LAD (41-63 days), which was on par with A4-4-2 and Matta Triveni. A significant difference in leaf area duration was noticed in all the four varieties with the addition of silica.

L x S interaction revealed that silica addition had no effect on leaf area duration at all the three shade levels.

Table 28 Influence of solar radiation and silica on leaf area duration (days) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	44.45	49.52	46.99	38.37	40.57	39.47	32.33	34.80	33.57	38.38	41.63	40.01
A4-4-2 (V_2)	46.90	45.13	46.02	46.90	46.53	46.72	26.52	27.60	27.06	40.11	39.75	39.93
A4-1-3 (V_3)	42.37	43.25	42.81	38.63	35.47	37.05	28.03	29.63	28.83	36.34	36.12	36.23
Matta Triveni (V_4)	40.83	41.77	41.30	49.43	46.47	47.95	33.13	29.90	31.52	41.13	39.38	40.26
Mean (L S)	43.64	44.92		43.33	42.26		30.00	30.48				
Mean (L)			44.28			42.80			30.24			
Mean (S)										38.99	39.22	

	L	S	V	LV	SV	LS	LSV
SE	0.33	1.11	1.25	2.16	1.76	1.92	3.05
CD (0.05)	1.28	NS	3.55	6.14	5.02	6.04	8.69

4.21 Chlorophyll Content

Total chlorophyll and chlorophyll a/b ratio were computed at harvest stage (Table 29 and 30).

Total chlorophyll content increased significantly with increase in shade levels. Chlorophyll a/b ratio was highest at 40 per cent shade (2.503 mg g^{-1}) and was lowest at 20 per cent shade (2.127 mg g^{-1}).

Silica application increased the total chlorophyll content and chlorophyll a/b ratio.

Among all the four varieties A4-4-2 recorded the highest chlorophyll content and chlorophyll a/b ratio, and was on par with Matta Triveni. Swarnaprabha recorded the lowest value.

As the shade increased from 0 to 20 per cent no significant change was observed in chlorophyll content in Swarnaprabha and Matta Triveni, but a significant increase was seen in A4-4-2 and A4-1-3. In all the four varieties chlorophyll content increased with increase of shade level from 20 to 40 per cent.

Swarnaprabha, A4-4-2 and A4-1-3 had shown no significant difference in chlorophyll a/b ratio between 0 and 40 per cent shade, but in Matta Triveni highest chlorophyll content (2.02) was recorded at 40 per cent shade level.

In S x V interaction Swarnaprabha and Matta Triveni had no significant effect on chlorophyll content with the addition of silica. But in A4-4-2 and A4-1-3 chlorophyll content increased with addition of silica.

Table 29 Influence of solar radiation and silica on total chlorophyll (mg g^{-1}) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	1.04	0.74	0.89	0.83	1.07	0.95	1.71	1.98	1.85	1.19	1.26	1.23
A4-4-2 (V_2)	1.25	0.74	1.00	1.36	1.33	1.35	1.67	3.15	2.41	1.43	1.74	1.58
A4-1-3 (V_3)	0.73	0.98	0.86	1.45	1.29	1.37	1.58	2.11	1.85	1.25	1.46	1.36
Matta Triveni (V_4)	1.03	1.04	1.04	1.37	1.25	1.31	1.91	2.13	2.02	1.44	1.47	1.46
Mean (L S)	1.01	0.88		1.25	1.24		1.72	2.34				
Mean (L)			0.94			1.24			2.03			
Mean (S)										1.33	1.48	

	L	S	V	LV	SV	LS	LSV
SE	0.42	0.04	0.05	0.08	0.07	0.07	0.11
CD (0.05)	0.17	0.13	0.13	0.23	0.18	0.22	0.32

Table 30 Influence of solar radiation and silica on chlorophyll a/b ratio of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	2.72	2.08	2.40	1.86	2.14	2.00	2.22	2.50	2.36	2.27	2.24	2.25
A4-4-2 (V_2)	2.25	2.52	2.39	2.18	2.41	2.30	2.83	2.31	2.57	2.42	2.41	2.42
A4-1-3 (V_3)	2.16	2.62	2.39	1.50	2.53	2.02	2.59	2.45	2.52	2.08	2.53	2.31
Matta Triveni (V_4)	2.20	2.48	2.34	2.21	2.19	2.20	2.53	2.59	2.56	2.31	2.42	2.37
Mean (L S)	2.33	2.43		1.94	2.32		2.54	2.46				
Mean (L)			2.38			2.13			2.50			
Mean (S)										2.27	2.40	

	L	S	V	LV	SV	LS	LSV
SE	0.02	0.02	0.04	0.06	0.05	0.04	0.09
CD (0.05)	0.07	0.07	0.10	0.18	0.15	0.12	0.25

A significant increase in chlorophyll a/b ratio was recorded only by A4-1-3 with the addition of silica (2.08 – 2.53).

Silica application increased the chlorophyll content only at 40 per cent shade. Chlorophyll a/b ratio was increased only in 20 per cent shade.

4.22 Proline content

Proline content was found to decrease significantly with the increase in shade level (Table 31).

No significant difference was observed in proline content with the addition of silica.

Among varieties Swarnaprabha recorded the highest value (61.34 mg g^{-1}) and Matta Triveni recorded the lowest value (38.24 mg g^{-1}). The other two varieties recorded intermediate values, which were on par with each other.

In Shade x Varietal interaction, Swarnaprabha in all the three shade levels recorded highest value. At 0 and 20 per cent shade levels Matta Triveni recorded the lowest proline content (33.75 and 31.45 mg g^{-1}).

Silica application increased the proline content in all varieties except Matta Triveni.

Silica addition decreased proline content at 20 and 40 per cent shade levels but at 0 per cent shade proline content increased with the addition of silica.

Table 31 Influence of solar radiation and silica on proline content (g g^{-1}) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	62.3	70.9	66.6	90.3	42.1	66.2	64.0	38.4	51.2	72.2	50.5	61.3
A4-4-2 (V_2)	49.7	69.8	59.8	27.1	64.0	45.6	55.0	23.0	39.0	43.9	52.3	48.1
A4-1-3 (V_3)	36.8	92.8	64.8	60.7	26.8	43.8	38.4	41.7	40.1	45.3	53.8	49.5
Matta Triveni (V_4)	35.8	31.7	33.8	24.5	38.4	31.5	51.1	48.0	49.6	37.1	39.4	38.3
Mean (L S)	46.2	66.3		50.7	42.8		52.1	37.8				
Mean (L)			56.2			46.7			45.0			
Mean (S)										49.6	49.0	

	L	S	V	LV	SV	LS	LSV
SE	0.36	0.81	0.89	1.54	1.26	1.40	2.18
CD (0.05)	1.40	NS	2.54	4.39	3.59	4.41	6.21

4.23 Relative water content

Relative water content was significantly influenced only by solar radiation. Maximum RWC was recorded in 40 per cent shade which was on par with 20 per cent shade and significantly superior to 0 per cent shade. Neither silica nor varieties differ significantly. LV and SV interaction were not significant (Table 32).

4.24 Root Weight

Mean values of root weight recorded at harvest stage was documented in Table 33. Root length was reduced significantly with increase in shade level. Maximum weight was observed in open situation (3.35 g).

Silica application significantly increased the root weight (1.6 to 2.1 g).

Matta Triveni recorded a significantly higher value (2.13 g) compared to the other three varieties, which were on par.

Interaction between variety and shade was found significant on root dry matter production. Matta Triveni registered the highest values (4.17 and 0.86 g) among all the varieties at 0 and 40 per cent shade levels. At 20 per cent shade level A4-1-3 recorded the highest root weight of 2.08 g.

S x V interaction revealed a significant increase in the root weight with the addition of silica. But variety A4-4-2 did not show any significant difference.

Table 32 Influence of solar radiation and silica on relative water content (per cent) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	74.7	76.0	75.4	77.9	80.6	79.3	81.8	82.7	82.3	78.1	79.8	79.0
A4-4-2 (V_2)	74.3	75.2	74.8	78.7	80.0	79.4	81.7	82.6	82.2	78.2	79.3	78.8
A4-1-3 (V_3)	76.1	76.9	76.5	78.6	79.3	79.0	81.3	82.0	81.7	78.7	79.4	79.0
Matta Triveni (V_4)	75.9	76.1	76.0	78.7	79.7	79.2	81.1	82.7	81.9	78.6	79.5	79.0
Mean (L S)	75.3	76.1		78.5	79.9		81.5	82.5				
Mean (L)			75.7			79.2			82.0			
Mean (S)										78.4	79.5	

	L	S	V	LV	SV	LS	LSV
SE	0.92	0.54	0.94	1.62	1.32	0.93	2.29
CD (0.05)	3.63	NS	NS	4.61	3.77	2.93	6.53

Table 33 Influence of solar radiation and silica on root weight (g $hill^{-1}$) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	1.86	4.15	3.01	1.42	1.59	1.51	1.00	0.65	0.83	1.43	2.13	1.78
A4-4-2 (V_2)	2.57	3.88	3.23	1.94	0.97	1.46	0.60	0.60	0.60	1.70	1.82	1.76
A4-1-3 (V_3)	2.25	3.76	3.01	1.25	2.90	2.08	0.83	0.77	0.80	1.44	2.48	1.96
Matta Triveni (V_4)	3.75	4.58	4.17	1.26	1.49	1.38	0.77	0.94	0.86	1.93	2.34	2.13
Mean (L S)	2.61	4.09		1.47	1.74		0.80	0.74				
Mean (L)			3.35			1.60			0.77			
Mean (S)										1.63	2.19	

	L	S	V	LV	SV	LS	LSV
SE	0.09	0.05	0.08	0.13	0.11	0.09	0.19
CD (0.05)	0.34	0.17	0.22	0.38	0.31	0.30	0.54

Silica application increased the root weight considerably only at 0 per cent shade (from 2.61 to 4.09 g).

4.25 Root length

Root length was reduced significantly, from 12.0 cm to 10.09 cm, with the advancement of shade levels (Table 34).

Silica application increased the root length significantly (8.6 to 11 cm).

Among varieties, A4-1-3 recorded the maximum root length of 10.89 cm and A4-4-2 recorded the minimum value of 8.84 cm. The other two varieties showed intermediate values and were on par.

In the open situation Swarnaprabha and Matta Triveni recorded maximum root length. At 20 and 40 per cent shade levels root length was maximum in A4-1-3.

In the absence of silica all varieties except A4-1-3 were on par with each other but in the presence of silica Swarnaprabha and A4-1-3 recorded higher root length compared to the other two varieties.

A significant increase in root length was recorded in all the three shade levels with the addition of silica (Table 34).

4.26 Root/Shoot ratio

Maximum root-shoot ratio was recorded in 0 per cent shade (0.198), which was significantly superior to the other two shade levels (Table 35).

Table 34 Influence of solar radiation and silica on root length (cm) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	9.75	15.17	12.46	9.00	11.42	10.21	6.42	7.50	6.96	8.39	11.36	9.88
A4-4-2 (V_2)	10.42	12.10	11.26	8.75	9.00	8.88	4.88	7.87	6.38	8.02	9.66	8.84
A4-1-3 (V_3)	10.33	12.00	11.17	10.10	15.17	12.64	7.42	10.30	8.86	9.28	12.49	10.89
Matta Triveni (V_4)	11.33	14.92	13.13	7.83	9.42	8.63	7.17	5.83	6.50	8.78	10.06	9.42
Mean (L S)	10.46	13.55		8.92	11.25		6.47	7.88				
Mean (L)			12.00			10.09			7.17			
Mean (S)										8.62	10.89	

	L	S	V	LV	SV	LS	LSV
SE	0.19	0.24	0.41	0.70	0.57	0.41	0.99
CD (0.05)	0.73	0.75	1.16	2.00	1.64	1.30	2.83

Table 35 Influence of solar radiation and silica on root shoot ratio of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	0.160	0.213	0.187	0.143	0.117	0.130	0.160	0.103	0.132	0.154	0.144	0.149
A4-4-2 (V_2)	0.203	0.170	0.187	0.117	0.150	0.134	0.113	0.147	0.130	0.144	0.156	0.150
A4-1-3 (V_3)	0.156	0.203	0.180	0.123	0.173	0.148	0.140	0.107	0.124	0.140	0.161	0.150
Matta Triveni (V_4)	0.246	0.230	0.238	0.123	0.180	0.152	0.127	0.137	0.132	0.165	0.182	0.174
Mean (L S)	0.191	0.204		0.127	0.155		0.135	0.124				
Mean (L)			0.198			0.141			0.129			
Mean (S)										0.151	0.161	

	L	S	V	LV	SV	LS	LSV
SE	0.01	0.01	0.01	0.02	0.01	0.01	0.02
CD (0.05)	0.02	NS	0.03	0.05	0.04	0.03	0.07

No significant response was recorded with the addition of silica.

The highest root/shoot ratio was recorded by Matta Triveni (0.174) which was significantly superior to the other three varieties which were on par with each other.

A significant reduction in ratio was observed in all the other varieties except A4 -1-3 when the shade level increased from 0 to 20 per cent.

No significant difference was shown by any of the four varieties with the addition of silica.

S x V interaction revealed no significant change with the addition of silica in all the three shade levels.

2.27 Incidence of leaf roller and stem borer

Incidence of Stem borer and leaf roller was significantly influenced by solar radiation (Table 36 and 37). Incidence of both the pests was significantly higher at 20 per cent shade level compared to open situation. As the shade level advanced to 40 per cent a significant increase in infestation was reported only in leaf roller.

Silica failed to influence the infestation of stem borer. But the incidence of leaf roller was significantly decreased with the application of silica.

Varieties failed to give any significant difference in the incidence of stem borer. But leaf roller infestation differed significantly among varieties.

All varieties except Swarnaprabha behaved similarly in this aspect. Swarnaprabha registered significantly lower incidence of leaf roller.

L x V interaction was not significant. S x V interaction revealed significance only in leaf roller infestation. Silica reduced the incidence of leaf roller significantly in A4-4-2.

L x S interaction has no effect on stem borer infestation. But the effect on leaf roller infestation was significant. Silica failed to give any significant influence on the incidence of leaf roller at 0 per cent shade level. But at 20 and 40 per cent shade levels silica played a significant influence in reducing leaf roller infestation.

4.28 Benefit : cost ratio (Actual)

The ratio decreased significantly with the increase in shade. The ratio recorded at 0, 20 and 40 per cent were 1.06, 0.82 and 0.34 respectively (Table 38).

Addition of silica increased the ratio significantly from 0.64 to 0.84.

No significant difference was seen among the four varieties.

L x V interaction revealed that at zero per cent shade level the maximum B:C ratio was recorded in Swarnaprabha (1.19), which was significantly superior to A4-44-2 (0.95) but was on par with A4-1-3 and Matta Triveni. There was no significant difference among varieties at 20 and 40 per cent shade. Cultivars A4-4-2 and Matta Triveni showed no significant difference when the shade level increased from 0 to 20 per cent.

Table 36 Influence of solar radiation and silica on incidence of stem borer (per cent) on rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SIO_2 (S_0)	100 kg ha^{-1} SIO_2 (S_1)	Mean (L_0 V)	Zero SIO_2 (S_0)	100 kg ha^{-1} SIO_2 (S_1)	Mean (L_1 V)	Zero SIO_2 (S_0)	100 kg ha^{-1} SIO_2 (S_1)	Mean (L_2 V)	Zero SIO_2 (S_0 V)	100 kg ha^{-1} SIO_2 (S_1V)	
Swarnaprabha (V_1)	1.22	1.22	1.22	1.30	2.77	2.04	2.65	1.83	2.24	1.72	1.94	1.83
A4-4-2 (V_2)	1.00	1.37	1.19	1.79	3.00	2.40	2.34	1.92	2.13	1.71	2.10	1.90
A4-1-3 (V_3)	1.00	1.67	1.34	1.49	2.19	1.84	1.99	1.95	1.97	1.49	1.94	1.72
Matta Triveni (V_4)	1.37	1.00	1.19	1.34	2.20	1.77	2.04	1.77	1.91	1.58	1.66	1.62
Mean (L S)	1.15	1.32		1.48	2.54		2.26	1.87				
Mean (L)			1.23			2.01			2.06			
Mean (S)										1.63	1.91	

	L	S	V	LV	SV	LS	LSV
SE	0.08	0.09	0.15	0.26	0.21	0.16	0.36
CD (0.05)	0.32	0.29	0.42	0.73	0.59	0.49	1.03

Table 37 Influence of solar radiation and silica on incidence of leaf roller (per cent) on rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	1.06	1.00	1.03	1.60	1.59	1.60	2.36	2.01	2.19	1.67	1.53	1.60
A4-4-2 (V_2)	1.00	1.06	1.03	2.27	1.67	1.97	2.56	2.36	2.46	1.94	1.70	1.82
A4-1-3 (V_3)	1.06	1.00	1.03	1.76	1.63	1.70	2.48	2.30	2.39	1.77	1.64	1.71
Matta Triveni (V_4)	1.02	1.00	1.01	1.63	1.48	1.56	2.50	2.56	2.57	1.72	1.68	1.70
Mean (L S)	1.04	1.02		1.82	1.59		2.48	2.31				
Mean (L)			1.03			1.70			2.40			
Mean (S)										1.78	1.64	

	L	S	V	LV	SV	LS	LSV
SE	0.03	0.02	0.05	0.08	0.07	0.04	0.11
CD (0.05)	0.10	0.08	0.13	0.23	0.19	0.13	0.32

There was no significant difference among varieties both in the presence and absence of silica.

In the absence of silica the ratio decreased significantly with the increase in shade level. No significant difference was noticed between zero and 20 per cent shade in the presence of silica (1.15 and 0.99 respectively). The lowest value was recorded in zero per cent shade (0.39).

Perusal of the data revealed the economic non-viability of the treatments. Only L_0 recorded B : C ratio more than one.

4.29 Benefit : cost ratio (revised)

B:C ratio was significantly influenced by solar radiation. The ratio decreased significantly (1.94, 1.42 and 0.60) with the increasing shade levels (Table 39).

Silica application increased the benefit cost ratio significantly from 1.24 and 1.39.

No significant difference was observed among the four varieties.

In L x V interaction Swarnaprabha (2.08) was significantly superior to Matta Triveni (1.80). The other two varieties recorded intermediate values. There was no significant difference among varieties at 20 and 40 per cent shade levels.

Table 38 Influence of solar radiation and silica on Benefit : cost ratio (actual) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	1.02	1.35	1.19	0.62	0.98	0.80	0.28	0.33	0.31	0.64	0.89	0.76
A4-4-2 (V_2)	0.94	0.96	0.95	0.66	1.04	0.85	0.27	0.39	0.33	0.62	0.80	0.71
A4-1-3 (V_3)	1.02	1.15	1.09	0.59	0.92	0.76	0.28	0.42	0.35	0.63	0.83	0.73
Matta Triveni (V_4)	0.93	1.13	1.03	0.69	1.03	0.86	0.36	0.42	0.39	0.66	0.86	0.76
Mean (L S)	0.98	1.15		0.64	0.99		0.30	0.39				
Mean (L)			1.06			0.82			0.34			
Mean (S)										0.64	0.84	

	L	S	V	LV	SV	LS	LSV
SE	0.033	0.031	0.041	0.071	0.058	0.054	0.101
CD (0.05)	0.128	0.099	NS	0.203	0.166	0.171	0.287

Table 39 Influence of solar radiation and silica on Benefit : cost ratio (revised) of rice cultivars

Treatments	0 per cent shade (L_0)			20 per cent shade (L_1)			40 per cent shade (L_2)			Mean (S V)		Mean (V)
	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_0 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_1 V)	Zero SiO_2 (S_0)	100 kg ha^{-1} SiO_2 (S_1)	Mean (L_2 V)	Zero SiO_2 (S_0 V)	100 kg ha^{-1} SiO_2 (S_1V)	
Swarnaprabha (V_1)	2.00	2.16	2.08	1.21	1.56	1.38	0.55	0.53	0.54	1.25	1.42	1.33
A4-4-2 (V_2)	1.85	2.07	1.96	1.28	1.66	1.47	0.50	0.62	0.56	1.21	1.45	1.33
A4-1-3 (V_3)	1.98	1.83	1.91	1.14	1.47	1.31	0.54	0.66	0.60	1.22	1.32	1.27
Matta Triveni (V_4)	1.82	1.80	1.81	1.35	1.65	1.50	0.70	0.67	0.68	1.29	1.37	1.33
Mean (L S)	1.91	1.97		1.24	1.59		0.57	0.62				
Mean (L)			1.94			1.41			0.60			
Mean (S)										1.24	1.39	

	L	S	V	LV	SV	LS	LSV
SE	0.027	0.032	0.039	0.067	0.055	0.056	0.095
CD (0.05)	0.105	0.102	NS	0.191	0.156	0.177	0.269

In the presence and absence of silica no significant difference was observed among varieties. Varieties A4-1-3 and Matta Triveni did not show any significant response with the application of silica.

L x S interaction revealed significant increase in benefit : cost ratio at 20 per cent shade level.

4.30 Correlation Studies

Correlation of growth, physiological and yield contributing characters with grain yield was worked out and presented in Table 40. Grain yield was positively correlated with all parameters except height of plant, number of tillers (30 DAS), total chlorophyll and chlorophyll a/b ratio. Grain yield was highly and positively correlated with culm strength (r = 0.811), number of tillers at 60 DAS (r = 0.815) LAI at 30 DAS (r = 0.709) and specific leaf weight at 60 DAS (r = 0.728).

Correlation values of growth, physiological and yield contributing characters with straw yield are presented in Table 41. Straw yield was positively correlated with all parameters except chaff percentage and relative water content. Above 50 per cent correlation was obtained with weight of panicle, number of productive tillers (r = 0.505) number of spikelets per panicle (r = 0.527) and CGR (r = 0.539).

Table 40 Values of simple correlation coefficient between grain yield and other parameters

Sl. No	Parameters	Correlation values
1	Height of plant (30 DAS)	-0.524
2	Height of plant (60 DAS)	-0.549
3	Height of plant (Harvest)	-0.376
4	Number of tillers (30 DAS)	-0.109
5	Number of tillers (60 DAS)	0.815
6	Number of tillers (Harvest)	0.619
7	Dry matter production (30 DAS)	0.483
8	Dry matter Production (60 DAS)	0.740
9	Dry matter production (Harvest)	0.889
10	Culm strength	0.811
11	Length of panicle	0.296
12	Weight of panicle	0.610
13	Number of production tiller	0.674
14	Number of spikelets per panicle	0.509
15	Number of filled grains per panicle	0.622
16	Chaff percentage	0.456
17	1000 grain weight	0.466
18	Crop growth rate	0.687
19	Relative growth rate	0.477
20	Net Assimilation Rate	0.483
21	Leaf area Index (30 DAS)	0.709
22	Leaf Area Index (60 DAS)	0.450
23	Specific leaf weight (30 DAS)	0.167
24	Specific leaf weight (60 DAS)	0.728
25	Leaf Area duration	0.654
26	Total chlorophyll	-0.707
27	Chlorophyll a/b	-0.056
28	Proline	0.229
29	Relative water content	0.508
30	Root length	0.687
31	Root weight	0.551
32	Root shoot ratio	0.657

Table 41 Values of simple correlation coefficient between straw yield and other parameters

Sl. No	Parameters	Correlation values
1	Height of plant (30 DAS)	0.003
2	Height of plant (60 DAS)	0.115
3	Height of plant (Harvest)	0.297
4	Number of tillers (30 DAS)	0.092
5	Number of tillers (60 DAS)	0.495
6	Number of tillers (Harvest)	0.367
7	Dry matter production (30 DAS)	0.229
8	Dry matter Production (60 DAS)	0.431
9	Dry matter production (Harvest)	0.475
10	Culm strength	0.431
11	Length of panicle	0.403
12	Weight of panicle	0.521
13	Number of production tiller	0.505
14	Number of spikelets per panicle	0.527
15	Number of filled grains per panicle	0.490
16	Chaff percentage	-0.76
17	1000 grain weight	0.382
18	Crop growth rate	0.539
19	Relative growth rate	0.532
20	Net Assimilation Rate	0.337
21	Leaf area Index (30 DAS)	0.291
22	Leaf Area Index (60 DAS)	0.495
23	Specific leaf weight (30 DAS)	0.326
24	Specific leaf weight (60 DAS)	0.485
25	Leaf Area duration	0.553
26	Total chlorophyll	0.476
27	Chlorophyll a/b	0.275
28	Proline	0.074
29	Relative water content	-0.216
30	Root length	0.469
31	Root weight	0.329
32	Root shoot ratio	0.102

DISCUSSION

5. DISCUSSION

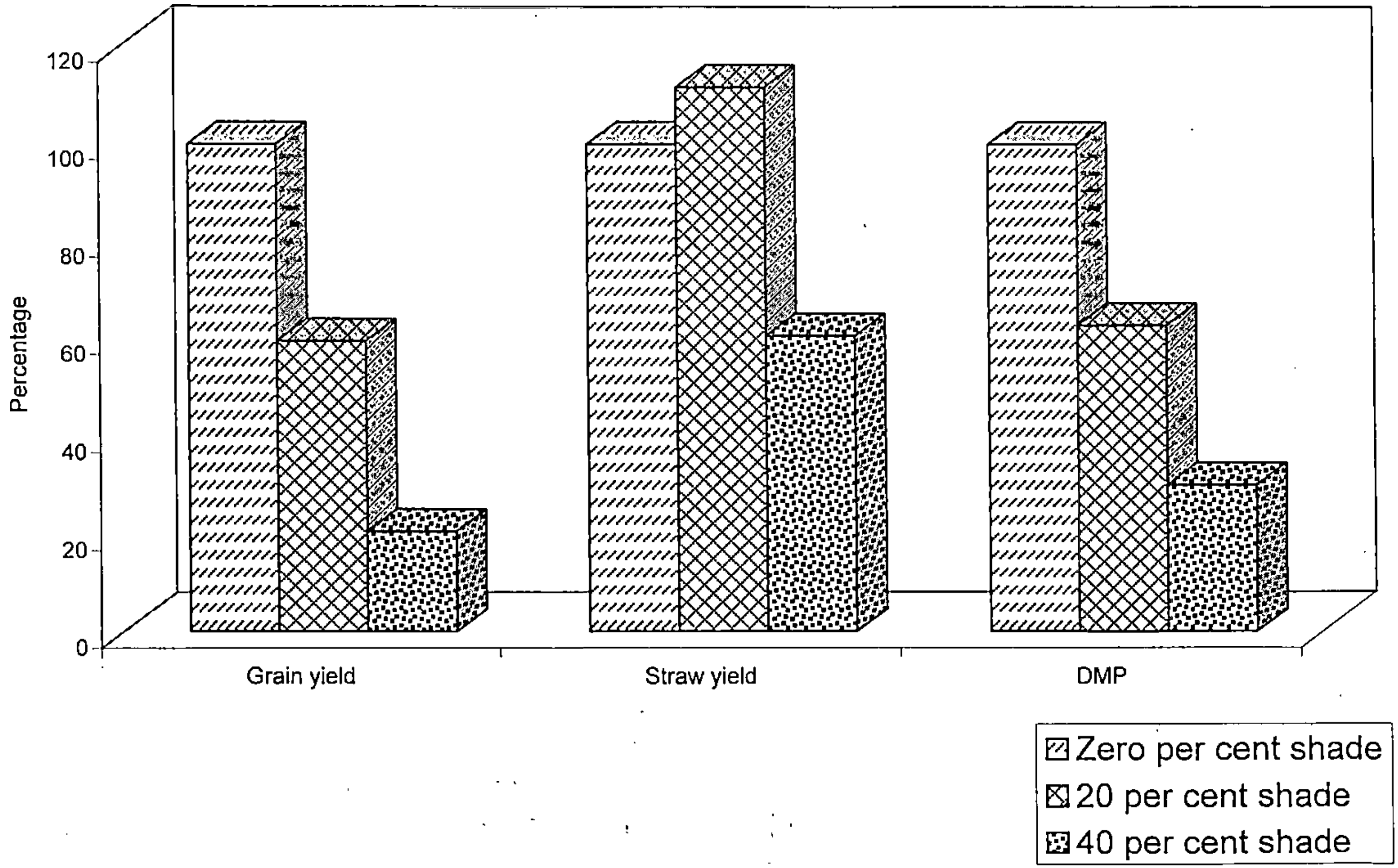
The result of the investigation entitled "Suitability of upland rice cultivars for shaded situations" is briefly discussed below, taking into consideration the previous information available in this subject and the data generated from this study. A critical analysis has been done to elicit possible trends and to draw definite conclusions.

5.1 Effect of solar radiation on upland rice

This investigation aims at evaluating and comparing the performance of rice as pure crop and also as intercrop in upland situation. For accomplishing this objective the performance of upland rice was studied under three levels of solar radiation (0, 20 and 40 per cent shade). Results of this study revealed significant influence of solar radiation on the growth and productivity of upland rice. Maximum grain yield (2764 kg ha^{-1}) was realised under open situation. A reduction in grain yield was observed with the increase in shade level (reduction in the intensity of solar reduction). Grain yield was significantly reduced by 41 and 80 per cent at 20 and 40 per cent shade levels respectively (Fig. 2). This reduction in grain yield with increase in shade level is the direct reflectance of the inhibitory effect of shade on various growth and yield attributes of upland rice. The results of this study corroborate with the findings of Viji (1995). She reported a significant decrease in grain yield in rice cultivars with the increase in shade level.

At 20 per cent shade level a significant reduction was observed in culm strength, SLW, LAI, LAD, and root activity. This reduction in photosynthates

Fig. 2 Effect of solar radiation intensities on grain yield, straw yield and dry matter production of upland rice (relative performance)

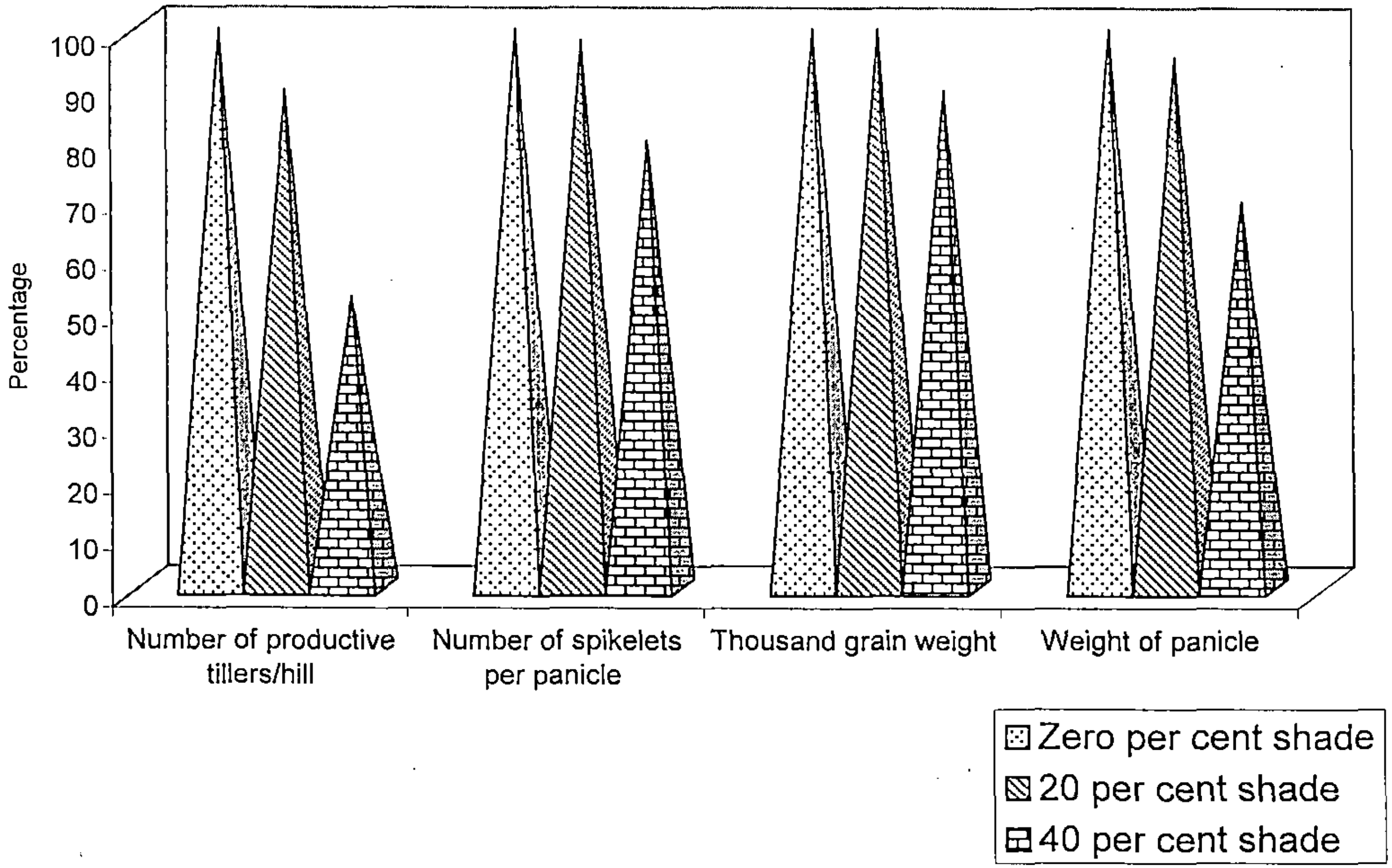


assimilating surface coupled with low root activity must have adversely affected the uptake as well as the assimilation of nutrients. Similar reduction in root activity at subdued light intensity was reported by Murty *et al.* (1975) Venkateswarlu and Srinivasan (1978) and Vijayalekshmi *et al.* (1987). This reduction in root activity was attributed to poor translocation of assimilates to root system. Wang *et al.* (1981) reported that low light intensity damaged the roots more adversely than other organs in rice. In this study also 55 and 77 per cent reduction was observed in root weight at 20 and 40 per cent shade levels respectively. This reduction in the root weight was mainly due to the production of slender unbranched roots under low light intensity as reported by Kawata and Saejima (1978). Reduction in LAI with decrease in solar radiation was earlier reported by Sreedharan and Vamadevan (1981).

A significant reduction in various yield attributes was also observed at 20 per cent shade level (Fig. 3). About 7 per cent reduction was observed in the number of filled grains per panicle compared to 0 per cent shade level and this has resulted in an increase in the percentage of chaff at this level of shade. Chaff percentage increased by 19 per cent compared to open situation. Yoshida and Parao (1976), Venkateswarlu (1977), Thangaraj and Sivasubramanian (1990) and Viji (1995) reported enhanced spikelet sterility under low light situation.

At 40 per cent shade level also a more or less similar response was observed. But the extent of reduction in growth and yield attributes was much higher than that observed at 20 per cent shade level (Fig. 2 and 3). Root length, root weight and root shoot ratio were reduced at the rate of 40 per cent,

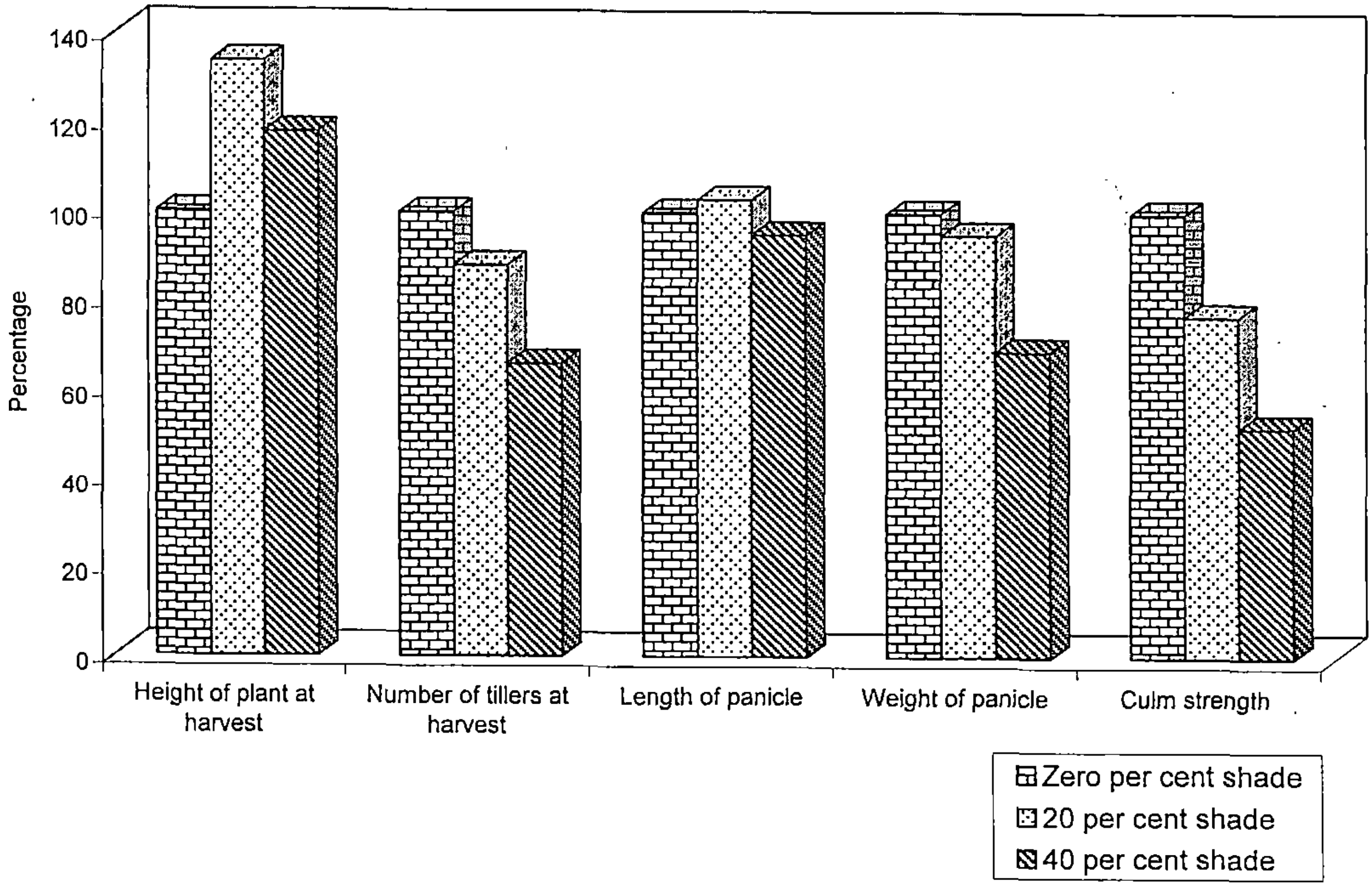
Fig. 3 Effect of solar radiation intensities on number of productive tillers, number of spikelets per panicle, thousand grain weight and weight of panicle of upland rice (relative perforamnce)



77 per cent and 35 per cent respectively at 40 per cent shade level. Similar reduction in the productivity under low light intensity was earlier reported by Vijayalekshmi *et al.* (1987), Thangaraj and Sivasubramanian (1990) and Viji (1995).

The effect of shade on straw yield was also significant, but the trend was not in line with that of grain yield (Fig. 2). Straw yields recorded at 0 and 20 per cent shade levels were on par, but at 40 per cent shade level a significant reduction in straw yield was obtained. Straw yield was reduced by 40 per cent and 46 per cent compared to 0 and 20 per cent shade levels respectively. The similar effect on straw yield at 0 and 20 per cent shade levels could be explained by evaluating the influence on plant height, culm strength and other growth attributes. Lincy (1986) has earlier reported a 14 per cent increase in straw yield in maize grown under partial shade situation. A significant increase in plant height was recorded with the increase in shade level (Fig. 4). At 20 per cent shade level 34 per cent increase in plant height was recorded at harvest stage. This positive response on height might be due to the increased synthesis of gibberellic acid. Janardhan and Murty (1980) and Murty and Murty (1981) also reported such an increase in plant height under subdued light intensity, which is attributed to the higher content of gibberellic acid. Though the plant height increased significantly, a corresponding significant increase was not observed in straw yield. This is due to the poor assimilation of photosynthates in the culm, which was evident from the reduction in culm strength observed in this study. The culm strength was reduced by 23 per cent at 20 per cent shade level (Fig. 4). At 40 per cent

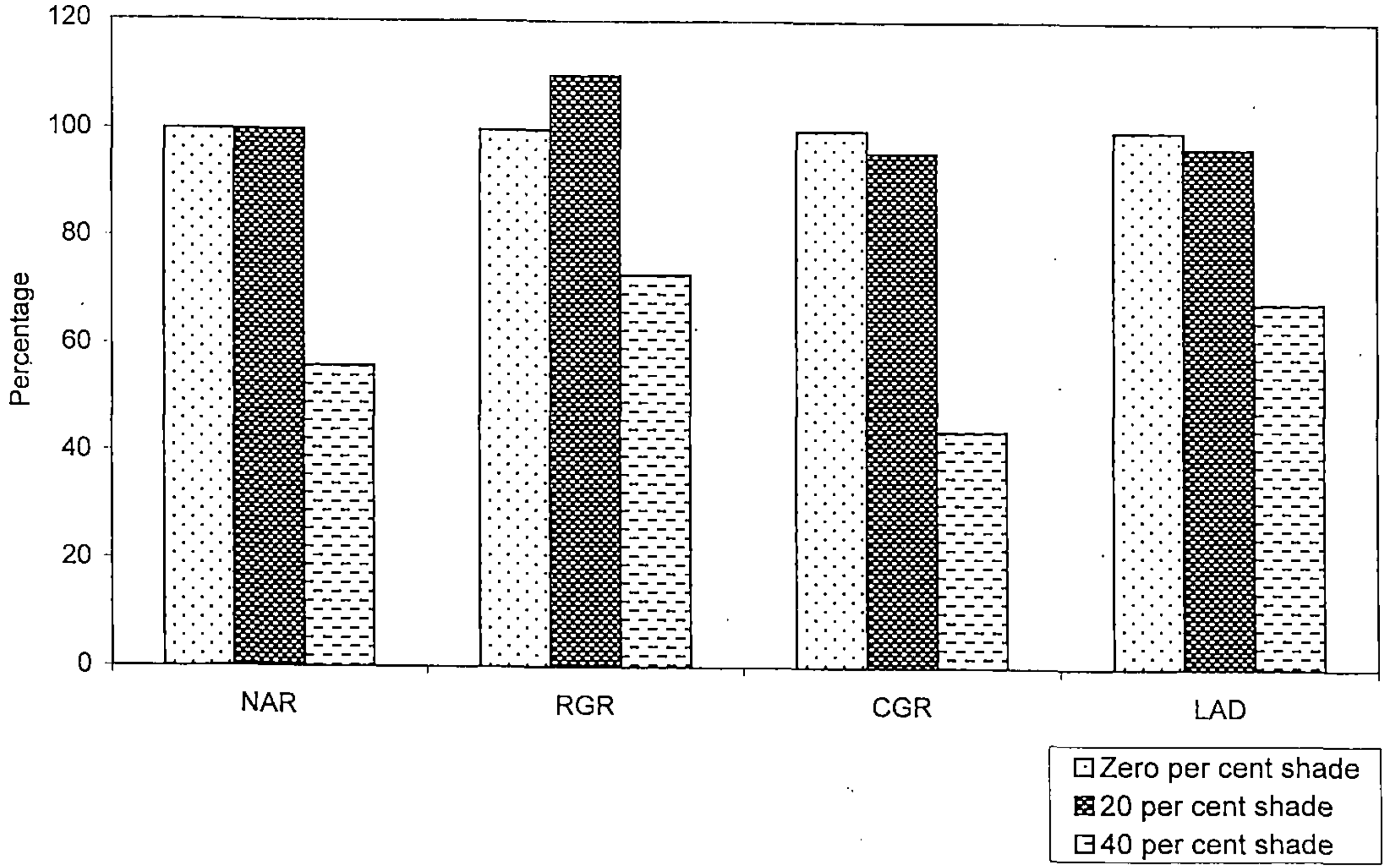
Fig. 4 Effect of solar radiation intensities on height of plant, numbre of tillers $hill^{-1}$, length of panicle, weight of panicle and culm strength of upland rice (relative perfromance)



shade level a significant reduction in straw yield was observed. Though the plant height increased at 40 per cent shade level this increase was not appreciably enough to bring about a favourable influence on straw yield. All other growth attributes that contribute to straw yield (tillering, LAI, SLW etc) were drastically reduced at 40 per cent shade level. The percentage reduction in tillering, LAI and SLW at 40 per cent shade compared to open situation was 23 per cent, 37 per cent and 10 per cent respectively. Results of the present study corroborate with the findings reported earlier. Singh *et al.* (1988) reported that low irradiance reduced the tillering capacity of rice to an extent of 13 to 50 per cent. Murty *et al.* (1973) reported a 25 per cent reduction in specific leaf weight under low light stress situation in rice.

Influence of solar radiation on DMP was also significant. DMP was reduced significantly with reduction in solar radiation (Fig. 2). Though the straw yield recorded at 0 and 20 per cent shade were on par that was not reflected in total DMP. The significant reduction in DMP at 20 per cent shade level was due to the significant reduction observed in grain yield at this level of shade. At 40 per cent shade level maximum reduction in DMP was observed, which was 70 and 53 per cent less than that recorded at 0 and 20 per cent shade levels respectively. This adverse effect on DMP was the cumulative result of the inhibitory effect of shade on grain and straw yields. Dineshchandra *et al.* (1986) reported a 12.97 per cent reduction in DMP under 50 per cent of normal light during active tillering and panicle initiation stages of rice. All physiological characters were adversely affected in subdued light intensity (Fig. 5). CGR, RGR, NAR, LAD, SLW and LAI were reduced at the

Fig. 5 Effect of solar radiation intensities on NAR, RGR, CGR and LAD of upland rice at harvest (relative performance)



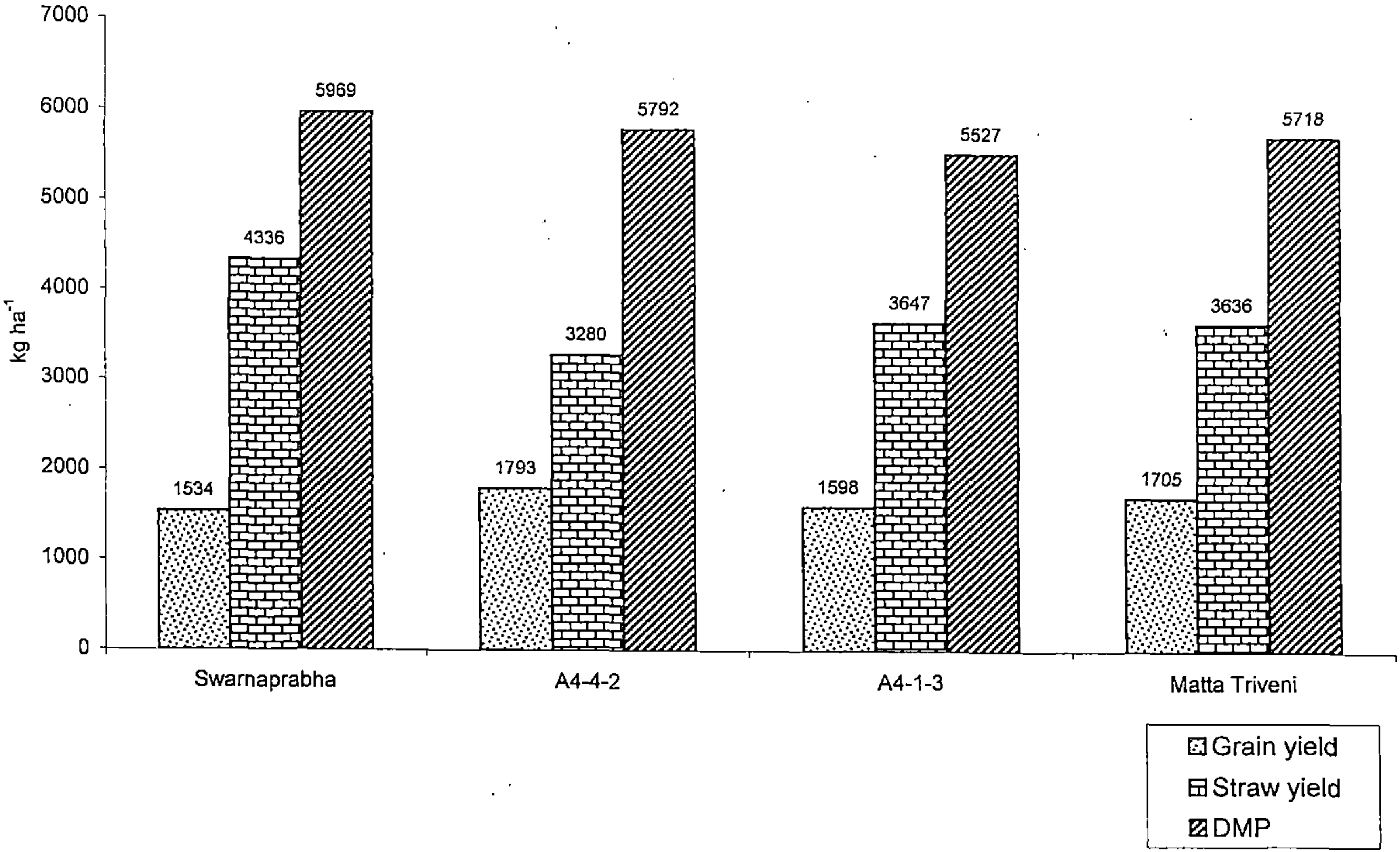
rate of 66 per cent, 27 per cent, 44 per cent, 29 per cent, 25 per cent and 32 per cent respectively, at 40 per cent shade compared to open situation.

5.2 Performance of rice cultivars in upland situation

Significant difference in the performance of rice varieties was observed in upland situation. A4-4-2 recorded maximum grain yield of 1.8 t ha^{-1}, which was on par with Matta Triveni (1.71 t ha^{-1}). Swarnaprabha and A4-1-3 were significantly inferior to A4-4-2 and Matta Triveni (Fig. 3). Valarmathi *et al.* (1996) had earlier reported an yield potentiality of 3.7 to 4 t ha^{-1} in A4-4-2 under upland situation. The better performance of Matta Triveni and A4-4-2 was mainly due to the higher number of productive tillers and increase in panicle length observed in these varieties. The number of productive tillers per hill in these varieties were about 14 per cent higher than that recorded in Swarnaprabha and A4-1-3.

Maximum straw yield was observed in Swarnaprabha (4.3 t ha^{-1}), which was significantly superior to all the other three varieties (Fig. 6). This better straw yield recorded in Swarnaprabha is mainly due to the tall nature of this particular cultivar, which recorded a height of 109 cm at the time of harvest. All other varieties were significantly inferior in plant height and the height ranged from 83 to 98 cm. Higher SLW also contributed to better straw yield in Swarnaprabha. But this superiority in straw yield was not reflected in grain yield. This indicates poor translocation of photosynthates from source to sink in Swarnaprabha, which is evident from the higher percentage of chaff and lower HI recorded in Swarnaprabha. A4-4-2, the variety which produced

Fig. 6 Grain yield, straw yield and DMP of rice cultivars undrer upland situation



maximum grain yield was found much inferior in straw yield. The dwarf nature of A4-4-2 had resulted in comparatively lesser straw yield.

5.3 Effect of solar radiation on chlorophyll and proline status of upland rice

A significant influence of solar radiation on chlorophyll content was observed in this study. Chlorophyll content of the plant increased by 32 and 115 per cent at 20 and 40 per cent shade level compared to control (open situation). A similar increase in chlorophyll content at subdued light intensity was earlier reported by Tangaraj and Sivasubramanian (1990), Voleti *et al.* (1991) and Viji (1995). But this increase in chlorophyll content has not promoted the productivity of upland rice in shaded situation. At 20 per cent shade level a significant reduction in chlorophyll a/b ratio was observed. This might be due to the higher intensity of long wave radiation prevalent in shaded situations. As a shade tolerance mechanism the crop might have synthesised more of chlorophyll b, which play the main part in the absorption of long wave radiation. Contrary to this at 40 per cent shade level a significant increase in the ratio was observed. This response observed at this level is very difficult to discuss. Some factor other than the intensity of solar radiation may be responsible for this response.

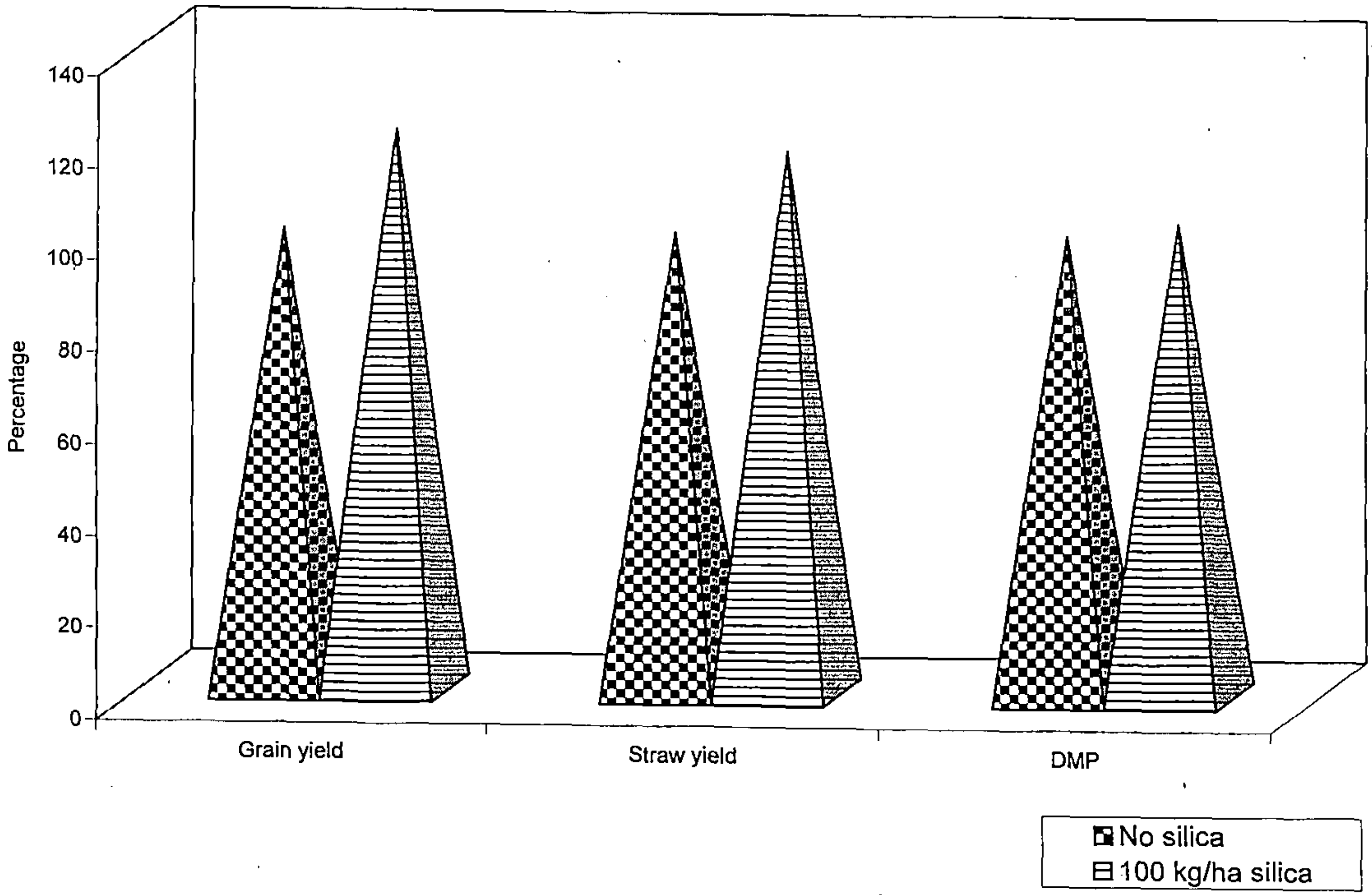
Effect of solar radiation on proline content was also significant. A significant reduction in the proline content was observed with the increase in shade level. Proline content decreased by 17 and 20 per cent at 20 and 40 per cent shade levels respectively compared to open situation. This may be due to the better soil moisture regime resulted from the reduced rate of evaporation and transpiration occurred under shaded situation. Under subdued light intensity, stomata remains partially closed and hence water loss from the plant occurs at a reduced rate (Sreekala, 1999). Proline content of crop was earlier reported by many workers as a determinant of drought tolerance in crops. The higher water content observed in leaves at 20 and 40 per cent shade levels also indicate the better moisture status prevalent in shaded situations. Maximum proline content was observed in the open situation. This showed that the crop was more subjected to moisture deficit at 0 per cent shade level. As a drought tolerance mechanism the plant might have synthesised more proline to combat the adverse effect.

A critical analysis of the effect of solar radiation reveals the possibility of raising rice under upland situation as pure crop and also as an intercrop (upto 20 per cent shade level). By growing rice in open situation it is possible to realize a grain yield of 2.5 t /ha and a straw yield of 4 t/ ha. At 20 per cent shade level a grain yield of about 1.6 t /ha and a straw yield of 4.6 t/ha can be obtained. Rice can be recommended as an intercrop in cropping systems, which permits 80 per cent transmission of solar radiation. So rice can be very well cultivated in coconut based cropping system where this level of solar radiation can be obtained. The result study also indicates that more than photosynthate assimilation translocation of this is much affected by reduction in solar radiation.

5.4 Effect of silicon nutrition on upland rice

Result of this study revealed significant influence of silica on upland rice. Both grain and straw yields increased significantly with the application of silica (1.5 to 1.8 t ha^{-1} and 3.4 to 4.0 t ha^{-1} respectively) (Fig. 7). Several beneficial effects have been attributed to Si in the physiology of the rice plant. It is found that Si gets deposited in the cell wall of the stem and thereby increases culm strength and also imparts increased resistance to the incidence of pests and diseases. In this study also a favourable increase in culm strength (1.7 per cent) was observed with Si nutrition. Application of silica has increased the root length and root weight significantly. Thakahashi *et al.* (1990) and Takahashi (1995) reported an increase in root activity with the addition of silica, which was due to the improved supply of carbohydrates to roots. This better root activity might have promoted better uptake of nutrients and consequently promoted the growth and yield parameters. The root length, root weight and root : shoot ratio were positively correlated with grain yield (r= 0.687, 0.551 and 0.657 respectively). Plant height at harvest stage was increased significantly (2.5 per cent) with the addition of silica. Similar increase in plant height by the application of silica was reported earlier by Azuma *et al.* (1961). Silica application increased the number of spikelets per panicle (9 per cent), filled grains per panicle (10.5 per cent) and panicle weight (10 per cent) significantly (Fig. 8). This superiority in yield contributing characters might be due to better translocation of assimilates, as evidenced from better harvest index (24 per cent increase than control). Miyoshi and Ishii (1960) reported better translocation of photosynthates from

Fig. 7 Effect of silica appliaction on grain yield, straw yield and DMP of upland rice (relative performance)

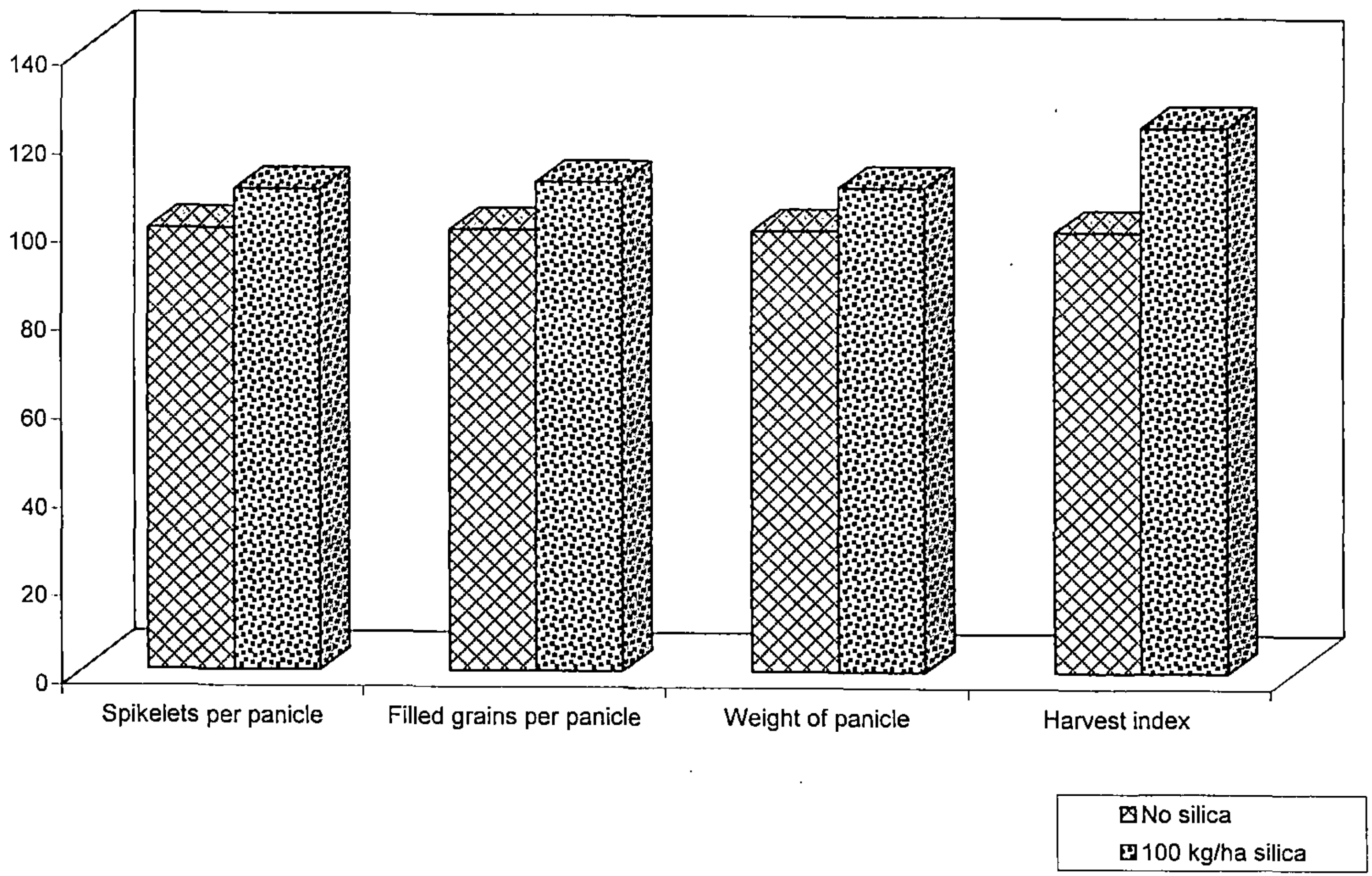


straw to ear by the application of silica. Better filling of grains by the application of silica was earlier reported by Vijayakumar and Koshy (1977) who found an increase in thousand grain weight by the application of silica. Kido (1958) also opined that 1000 grain weight increased significantly by the application of silica.

Beneficial effects of applied Si on the yield of upland rice have been observed by Garrity *et al.* (1990). They found that Si application increased the yield of rice in Ultisol with very high P fixing capacity. This study was conducted in Oxisol where P fixing capacity is also high (45 per cent) (Sheeja, 1990). Here silica addition produced a 21.7 per cent increase in grain yield. This significant increase might be the cumulative effect of better spikelet number per panicle (r =0.509) filled grains per panicle (r =0.622) and weight of panicle (r = 0.610). Straw yield also increased significantly by 18 per cent with the addition of silica, which might be due to the increased height (2.5 per cent) DMP (3.4 per cent) and number of tillers (6.8per cent) at harvest stage. Favourable influence of silica on the synthesis of proline might be another reason for the better response obtained with silica application. Several workers suggested that proline content could be used as a measure of drought resistance (Bernett and Naylor, 1966, Singh *et al.*, 1972). Drought being a major factor that limits productivity of rice in upland situation, higher rate of accumulation of proline might have been beneficial.

This study reveals the possibility of enhancing productivity of upland rice by applying S_1O_2 @ 100 kg ha^{-1}.

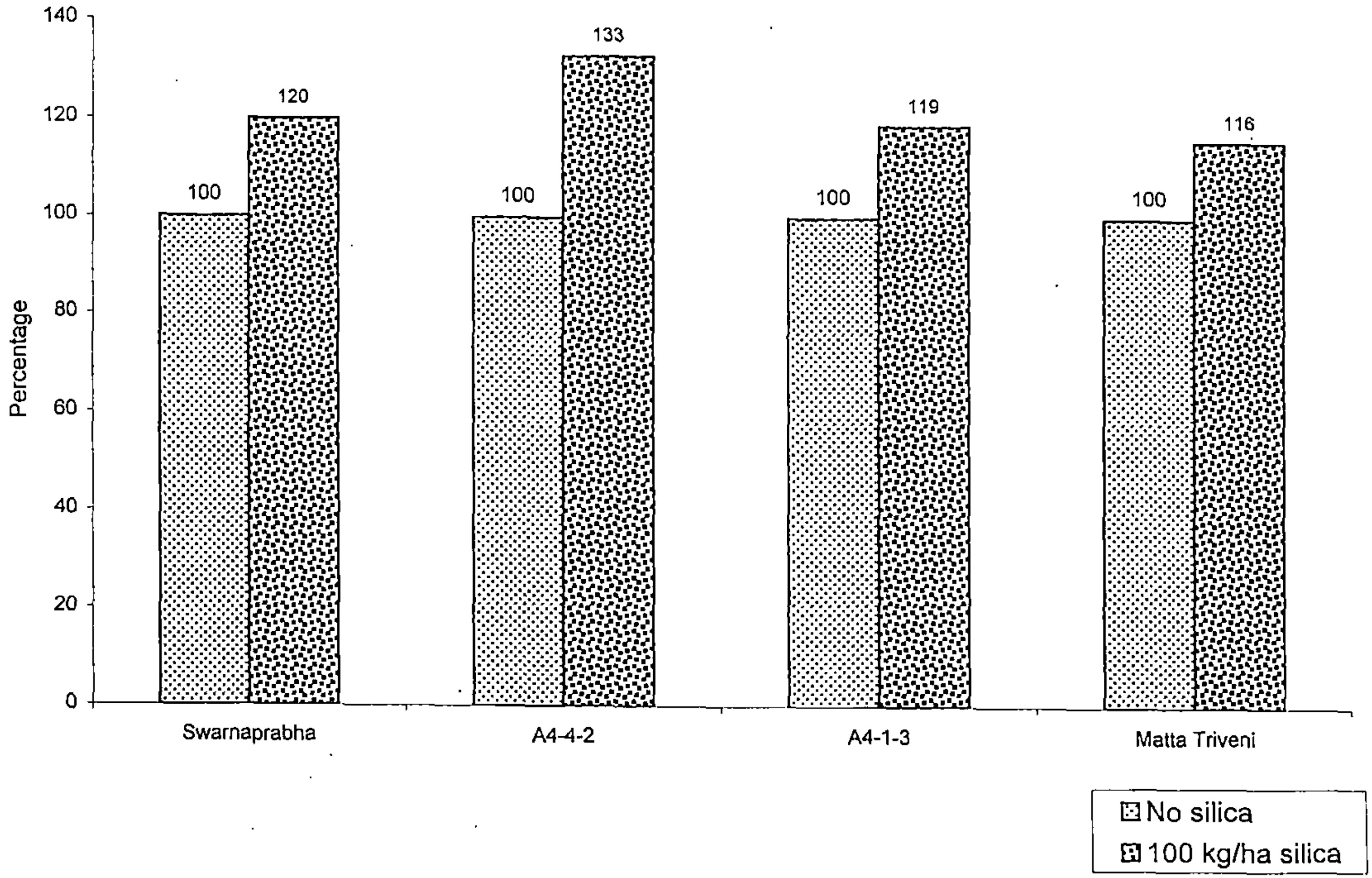
Fig. 8 Effect of silica application on spikelets per panicle, filled grains per panicle, weight of panicle and harvest index of upland rice (relative performance)



5.5 Differential response of rice cultivars to silicon nutrition

Differential response of rice cultivars to silicon nutrition was observed. Maximum response to silica application was obtained in A4-4-2 where grain yield increased significantly by 33 per cent (Fig. 9). A significant 20 per cent grain yield increase was observed in Swarnaprabha, 19 per cent in A4-1-3 and 16 per cent in Matta Triveni. This better response of A4-4-2 might be due to the higher reduction in chaff percentage (20 per cent) and better HI registered with the addition of silica. Chaff percentage reduced by 20 per cent in A4-4-2 while in other varieties the reduction was in the range of 4.3 per cent. A4-4-2 registered 58 per cent increase in HI with the application of silica, while the percentage increase in HI in the other varieties ranged between 16 to 30 per cent, which indicated the better translocation of assimilates from source to sink in this variety. A4-4-2 also showed a higher rate of increase in height of the plant at harvest (5 per cent), number of tillers at harvest (17.2 per cent), proline content (19 per cent) and chlorophyll content (22 per cent) with the addition of silica. A similar beneficial effect of applied silica on tiller number and grain filling has been reported by Burbey *et al.*, (1988) in upland rice (Vr. Danaubanch) grown in Ultisol in west Samatra. Sreenivasan (1936) reported an increase in height by the application of Sodium silicate in conjunction with green manure. Differential response of cultivars to nutrients was reported by Tisdale *et al.* (1995) which is attributed mainly to the genetic make up of the cultivar.

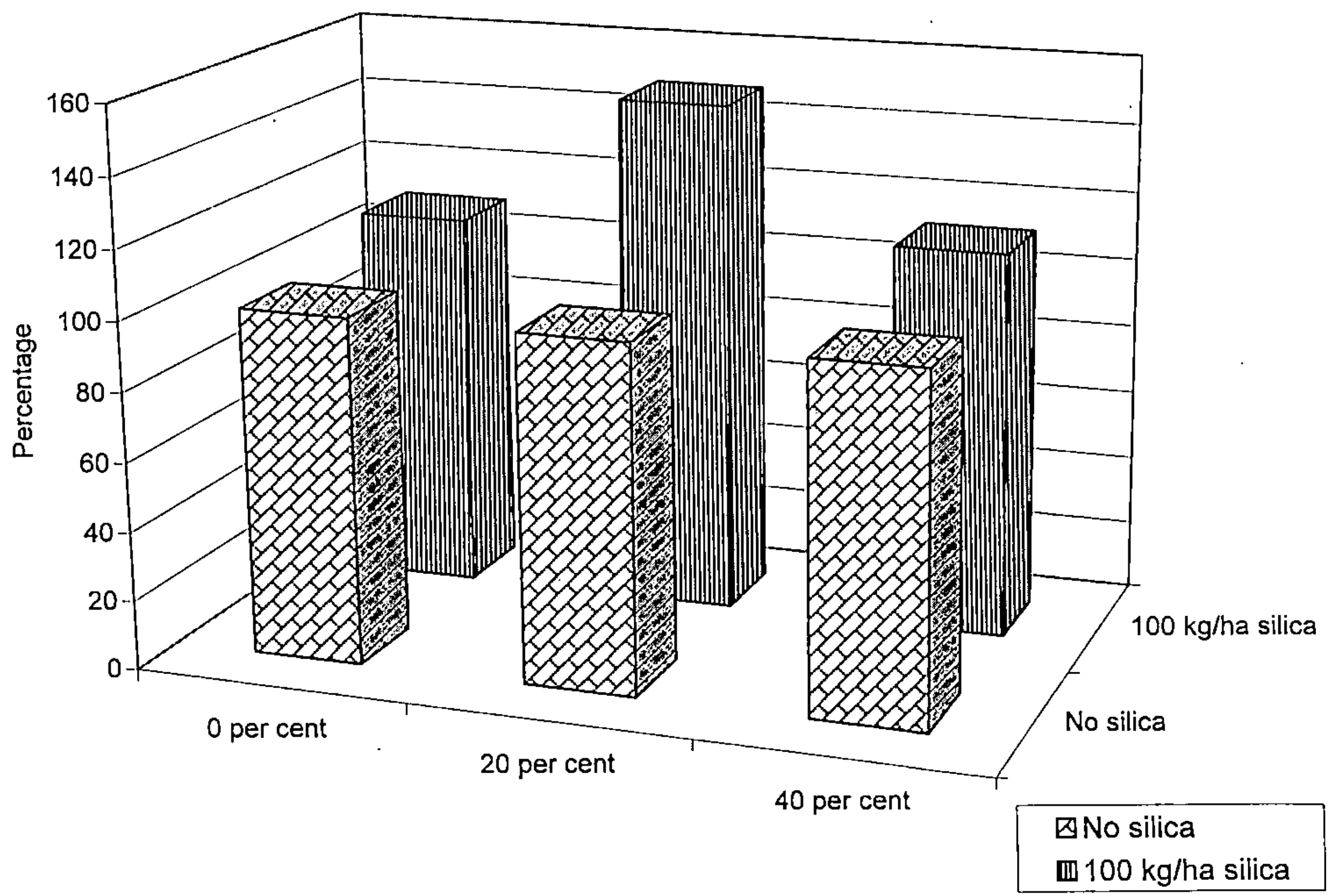
Fig. 9 Effect of silica application on grain yield of rice cultivars (relative performance)



5.6 Response of upland rice to silica under various levels of shade

The interaction between silica levels and light intensity was also found significant. In open situation only 10 per cent increase in grain yield was observed with the application of silica. At 20 per cent shade level the increase was 49 per cent and it was 12 per cent at 40 per cent shade level (Fig. 10). This better response of silica in shaded situations might be due to the better moisture regime of the soil, due to from low rate of evaporation and transpiration, which might have facilitated better uptake of silica. Higher water content of soil might have led to greater uptake of silicon. Tisdale *et al.* (1995) had also reported that uptake of silicon is passive, hence was more favourably influenced by moisture regime. The positive effect of Si on leaf erectness was earlier reported by Yoshida *et al.* (1969), and Kang (1985), which is beneficial in situations where low light intensity while limits photosynthesis. A further role of silica in light relationship within leaf cells of sugarcane was indicated by research at the University of Michigan. Silica cells apparently provide windows in the epidermal system, which allow more light to be transmitted to photosynthetic mesophyll and cortical tissues below the epidermis of leaves and stems respectively than that would occur if silica cells were absent (Tisdale *et al.,* 1995). The favourable role of Si in light relationship and maintenance of better soil moisture regime might have resulted in better response at 20 per cent shade level compared to the response obtained in open situation. At 40 per cent shade level the percentage increase was much less than that at 20 per cent shade level, which was a direct reflection of the inhibitory effect of low light intensity.

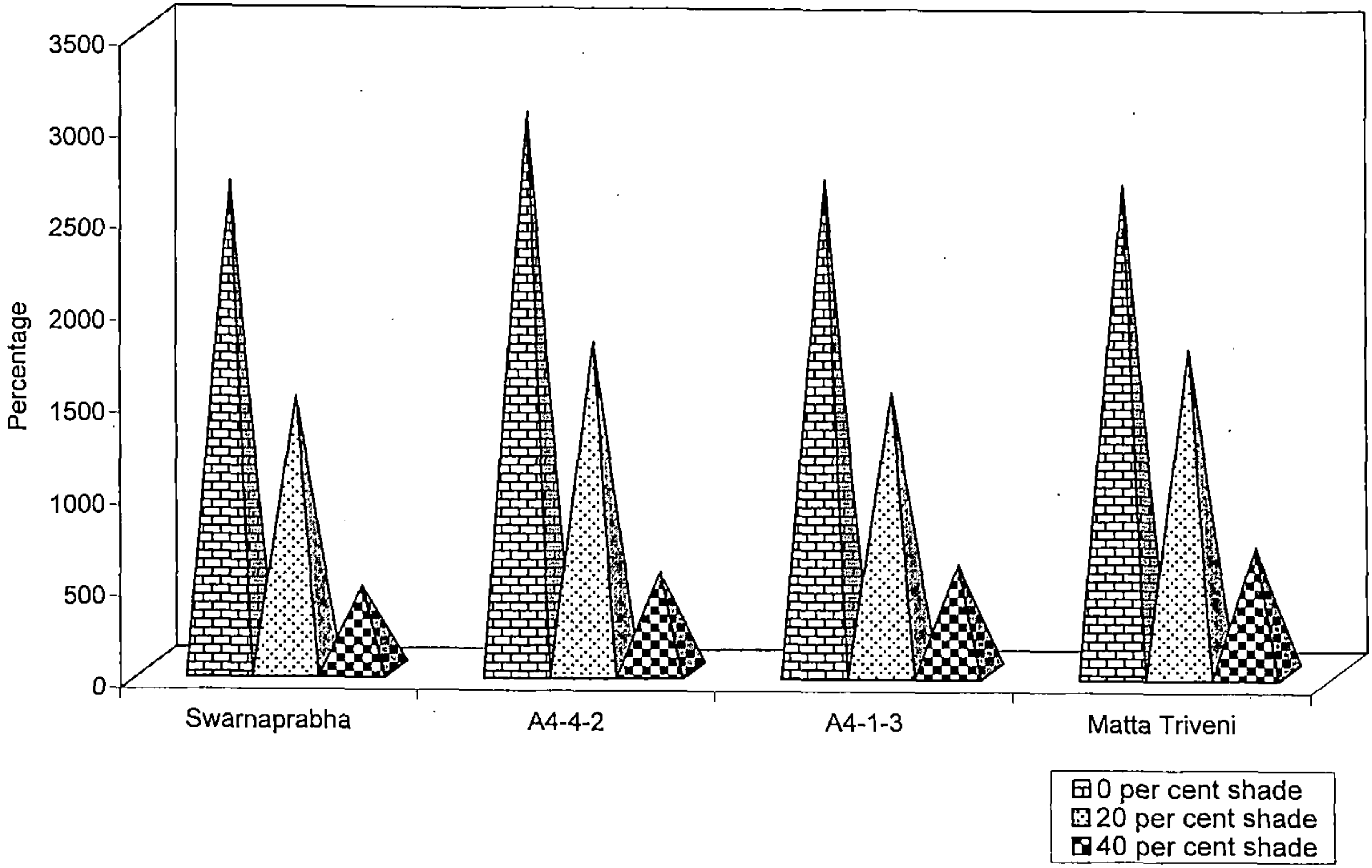
Fig. 10 Effect of silica application on grain yield of rice in different light intensities (relative performance)



5.7 Influence of light intensity on growth and productivity in different rice cultivars

Result of the study indicated varietal difference in rice in responding to varied light intensities. In open situation the cultivar A4-4-2 top seeded all other varieties by recording a grain yield of about 3 t ha^{-1} (Fig. 11). In open situation A4-4-2 recorded a minimum chaff percentage and that indicate a better source sink relationship in this cultivar in open situation, which has resulted in maximum productivity of A4-4-2 under open situation. At 20 per cent shade level A4-4-2 and Matta Triveni performed better than other varieties. At this shade level Swarnaprabha and A4-1-3 were on par but were inferior to A4-4-2 and Matta Triveni. This poor grain yield in A4-1-3 and Swarnaprabha might be due to poor translocation of photosynthates. Swarnaprabha and A4-1-3 recorded low harvest index values at 20 per cent shade (0.243 and 0.272 respectively) levels compared to A4-4-2 and Matta Triveni. These two varieties recorded harvest index of 0.352 and 0.364 respectively. But at 40 per cent shade all varieties were on par and recorded about 80 percent reduction in yield compared to open situation. The intensity of solar radiation is so inadequate to give any response at this shade level. This type of cultivar difference in tolerating low light intensity was earlier reported by Janardhan and Murthy (1978). They opined that cultivars like PTB-10 and T-141 possessing higher photosynthetic rate, NAR, greater chlorophyll content and thicker leaves (SLW) adapt better under low light situations. Varietal difference in shade tolerance in rice was also reported by Venkateswaralu (1977) and Viji (1995).

Fig. 11 Effect of solar radiation intensities on grain yield of rice cultivars



5.8 Benefit-Cost analysis

Computation of economics (Table 38) revealed that none of the main effects was found economically viable. Only Lo reported B : C ratio more than 1, here also the value is not appreciable (1.06). This poor response on economics is due to the high cost of sodium silicate (Rs 44 / kg), the source of Si used in this study.

Cheaper Source of silica is available. The data indicated in Table 39 is computed by substituting sodium silicate with a cheaper source of silica (@ Rs. 5 per kg) . Perusal of data furnished in Table 39 revealed significant influence of solar radiation on economics of upland rice cultivation. Maximum B:C ratio observed in open situation (1.94) revealed the significant influence of solar radiation on productivity of upland rice. Cultivation of upland rice at 20 per cent shade level was also found economically viable (B:C ratio 1.41).

Significant influence was observed in Si application. B.C ratio was increased significantly by 31 per cent with Si application.

Economic viability was revealed by all varieties. Except A4-1-3 all other varieties recorded B:C ratio of 1.33, while the former recorded a B:C ratio of 1.27.

B:C ratio of more than 2.0 was reported by $L_0S_1V_1$ (2.16) and $L_0S_2V_2$ (2.07). Result of this study indicate the feasibility of tapping maximum profit by cultivating Swarnaprabha and A4-4-2 in open situation with the addition of silicon. A-4-4-2 retains its superiority at 20 per cent shade level also but

Swarnaprabha was found significantly inferior to A4-4-2 at 20 per cent shade level. Matta Triveni recording a B:C ratio of 1.65 was found on par with A4-4-2 at 20 per cent shade level.

Very low B : C ratio reported at 40 per cent shade level indicate the non-remunerative nature of the treatments at the level of shade.

The variations in the B:C ratio registered in various treatments is a direct reflection of the input cost as well as the productivity realised from various treatments.

5.9 Practical utility of the experimental results

- Rice can be profitably cultivated in upland both as pure and as intercrop in cropping systems which permit 80 per cent transmission of solar radiation.

- The productivity of upland rice can be increased with the application of silica.

- It is possible to realise an yield potential of about 2.5 t ha^{-1} from Swarnaprabha, A-4-4-2, A-4-1-3 and Matta Triveni in open situation.

- A-4-4-2 and Matta Triveni can be cultivated as intercrop.

- It is agronomically optimum and economically viable to grow upland rice as pure crop and also as intercrop with the addition of silica.

5.10 Future line of work

⇒ Screening of different rice cultivars for upland situation

⇒ Screening of upland rice cultivars for intercropping systems

⇒ Detailed exploration on the dynamics of silicon nutrition by using different sources of silica and conducting more investigations regarding the availability and uptake of silica by upland rice cultivars

⇒ Standardization of agro-technique for intercropped rice

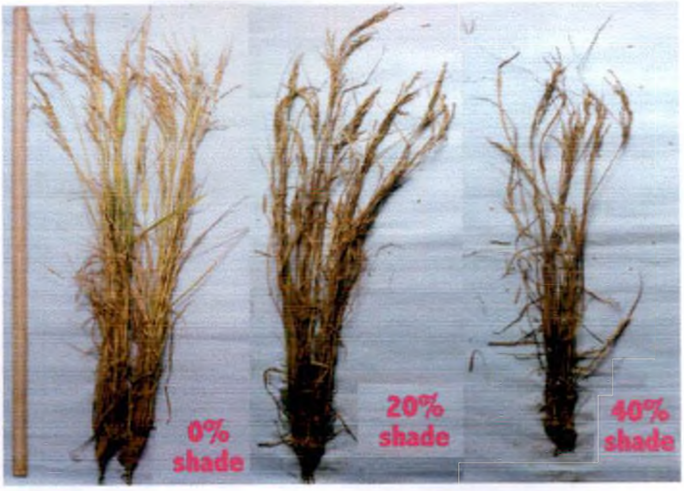
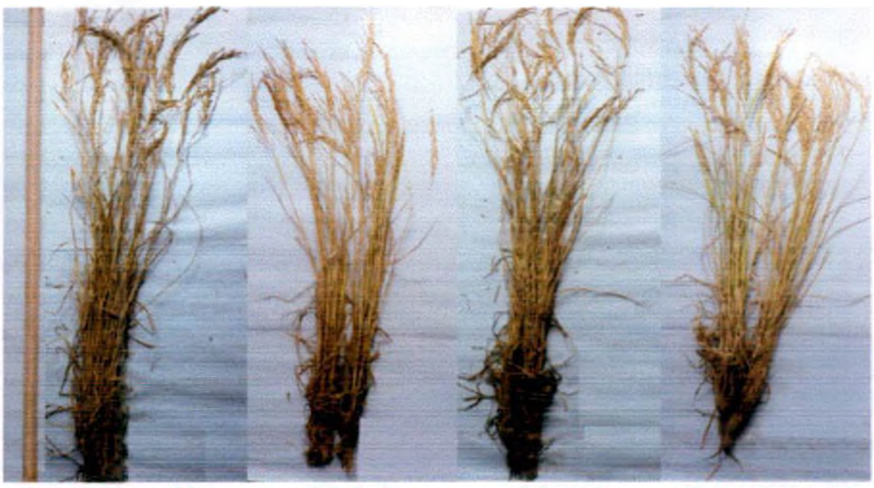


Plate 2. Performance of rice in different shade levels

No silica 100 kg ha^{-1} silica

Plate 3. Relative performance of rice in the presence of silica



Swarnaprabha A4-4-2 A4-1-3 Matta Triveni

Plate 4. Performance of rice cultivars in upland situation

SUMMARY

6. SUMMARY

The study entitled 'suitability of upland rice cultivars for shaded situations' was carried out at the instructional farm attached to the College of Agriculture, Vellayani during the kharif season of 1999. The main objective of the study was to assess the effect of solar radiation and silica on the performance of four upland rice cultivars and also to compute the economics of the study. The treatments consisted of three shade levels (0, 20 and 40 per cent) two levels of silica (zero and 100 kg ha^{-1} silica) and four rice cultivars (Swarnaprabha, A4-4-2, A-4-1-3 and Matta Triveni). The experiment was conducted in split-split plot design with three replications.

The results of the investigation are summarized below.

1. The height of the plant increased significantly both at 20 and 40 per cent shade levels compared to open situation at all the three growth stages (30 DAS, 60 DAS and at harvest). Maximum height was reported at 20 per cent shade level at 60 DAS and at harvest. Among the four varieties Swarnaprabha recorded the maximum height.

2. At 60 DAS the tiller number decreased significantly with the successive increase of shade levels. Application of silica increased the tiller production significantly at 60 DAS. No significant deference was observed in tiller production among varieties.

3. In open situation and at 40 per cent shade no significant difference was seen among varieties in number of productive tillers per hill, number of spikelets per panicle, number of filled grains per panicle, length of

panicle and weight of panicle. Swarnaprabha recorded maximum chaff percentage at 40 per cent shade level which was on par with A4-4-2 and Matta Triveni while the lowest percentage was reported in A-4-1-3. Varietal difference was not observed in number of filled grains per panicle and thousand grain weight at 20 per cent shade level.

4. In the presence and absence of silica no varietal difference was observed in productive tillers per hill, number of spikelets per panicle, thousand grain weight, chaff percentage, length of panicle, and weight of panicle. At 20 per cent shade level no significant change was observed in number of productive tillers per hill, number of spikelets per panicle, number of filled grains per panicle, length of panicle and weight of panicle with the addition of silica. But addition of silica decreased the chaff percentage and thousand grain weight significantly at this shade level.

5. No significant difference was observed in CGR, RGR, SLW at 30 DAS and LAI at 60 DAS as the shade level increased from 0 to 20 per cent. At 20 per cent shade level LAD, proline content SLW at 60 DAS, LAI at 30 DAS, chlorophyll a/b ratio, culm strength, root weight, root length and root shoot ratio decreased significantly compared to open situation. But relative water content and total chlorophyll content increased significantly.

6. Silica failed to give any significant difference in CGR, RGR, NAR, SLW, LAI, LAD, RWC, and root shoot ratio, but total chlorophyll

content chlorophyll a/b ratio, root length and root weight increased significantly.

7. NAR, RGR, CGR, SLW, LAI, LAD, proline content, relative water content, culm strength, root weight, root length and root shoot ratio decreased significantly but total chlorophyll and chlorophyll a/b ratio content increased significantly with the advancement of shade level from 0 to 40 per cent.

8. Varietal difference was not observed in NAR, RGR, CGR, LAI and relative water content. Root weight and root shoot ratio were significantly higher in Matta Triveni and Swarnaprabha and A4-1-3 registered maximum root length.

9. Yield contributing characters were significantly influenced by solar radiation. At 40 per cent shade level yield contributing characters viz., number of productive tillers, number of spikelets per panicle, thousand grain weight, length of panicle and weight of panicle decreased significantly, but chaff percentage increased significantly compared to 0 and 20 per cent shade levels.

10. The DMP decreased significantly at 60 DAS and at harvest with the successive increase in shade levels.

11. Grain yield decreased significantly with the successive increase in shade levels. (2764 kg ha^{-1}, 1641 kg ha^{-1}, and 568 kg ha^{-1} at 0, 20 and 40 per cent shade levels respectively). Silica increased the grain yield

significantly. In the open situation maximum grain yield was recorded in A4-4-2. At 20 per cent shade in A4-4-2 registered maximum grain yield which was on par with A4-1-3 and Matta Triveni. Grain yield increased significantly in all varieties with the addition of silica. Grain yield increased significantly at 0 and 20 per cent shade levels with the addition of silica (2633 kg ha^{-1} to 2894 kg ha^{-1} and 1317 kg ha^{-1} to 1965 kg ha^{-1} respectively). But at 40 per cent shade no significant difference was seen.

12. The B:C ratio decreased significantly with the increase in shade . Addition of silica increased the B:C ratio significantly from 0.64 to 0.84. No significant difference was observed in B:C ratio among the four varieties.

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* Original not seen

APPENDIX

APPENDIX – I

Data on weather parameters during cropping period

Standard week	Relative humidity (%)	Temperature (^0C)		Sun shine hours	Rainfall (mm) (Weekly total)
		Maximum	Minimum		
25	80.6	31.0	24.24	9.3	24.4
26	77.5	30.8	24.00	9.5	7.4
27	84.5	28.3	23.30	4.6	25.8
28	88.1	28.9	23.6	7.3	75.6
29	83.0	28.4	23.34	3.6	22.2
30	85.0	28.9	23.10	7.8	37.2
31	85.4	29.5	23.50	7.1	31.0
32	80.5	30.3	24.32	8.4	1.2
33	82.5	29.7	23.70	9.4	67.6
34	82.8	29.6	23.50	7.2	4.6
35	80.4	29.6	23.30	6.9	2.9
36	79.6	30.5	23.70	8.4	2.5
37	76.2	31.2	23.90	9.7	0.8
38	76.0	32.2	24.40	9.8	-
39	84.5	30.15	23.60	6.4	12.2
40	86.7	28.9	23.20	6.1	106.8
41	82.36	29.83	23.71	2.8	9.66

One decimal is enough

SUITABILITY OF UPLAND RICE CULTIVARS (*Oryza sativa* L.) FOR SHADED SITUATIONS

By

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ABSTRACT OF THE THESIS
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2000

ABSTRACT

A field experiment was conducted at College of Agriculture, Vellayani, to assess the effect of varying levels of solar radiation and silica on the performance of upland rice cultivars. This study also aimed at computing the economics of upland rice cultivation and silica application. The treatments included three shade levels (0, 20 and 40 per cent), two levels of silica (no silica and 100 kg ha^{-1} silica) and four varieties (Swarnaprabha, A4-4-2, A4-1-3 and Matta Triveni). Shade was imposed by using shade nets of appropriate shade levels and silica was applied as sodium silicate. The experiment was laid out in split-split plot design.

The results of the investigation are summarised below.

Solar radiation influenced growth attributes significantly. A significant reduction was observed in tillering, LAD, proline content, SLW, LAI, culm strength, root weight, root length and root-shoot ratio as the shade advanced to 20 and 40 per cent levels. Among the growth attributes only plant height and chlorophyll content increased significantly with increase in shade level.

Yield contributing characters were also significantly influenced by solar radiation. Maximum number of productive tillers, spikelets per panicle, thousand grain weight, length and weight of panicle was observed in the open situation.

A significant reduction in grain yield was observed with increase in shade level. Maximum productivity was registered at 0 per cent shade level which was 68 and 387 per cent higher than 20 and 40 per cent shade levels.

Same trend was observed in DMP. Maximum straw yield was recorded at 20 per cent shade which was on par with zero per cent shade.

Application of silica increased total chlorophyll content, chlorophyll a/b ratio, root length and root weight significantly. Grain and straw yield increased significantly by 22 and 18 per cent with the application of silica.

In the open situation A4-4-2 recorded maximum grain yield. At 20 per cent shade level A4-4-2 and Matta Triveni top seeded other cultivars. Swarnaprabha recorded maximum straw yield in the open situation. Compared to open situation at 20 per cent shade level straw yield increased significantly in A4-4-2 and Matta Triveni.

Sodium silicate was found as an un-economical source of Si for upland rice. Silica nutrition can be made economical by substituting sodium silicate with a cheaper source of silica.

B : C ratio reduced significantly with increase in shade level. The treatment $L_0S_1V_1$ registered maximum B : C ratio of 1.35.