PERFORMANCE OF BASMATI RICE (*Oryza sativa* L.) VARIETIES AS INFLUENCED BY DATE OF PLANTING

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Thesis submitted in partial fulfillment of the requirement
For the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2002

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DECLARATION

I hereby declare that this thesis entitled **"Performance of Basmati rice (*Oryza sativa* L.) varieties as influenced by date of planting"** 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 to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Performance of Basmati rice (*Oryza sativa* L.) varieties as influenced by date of planting"** is a record of research work done independently by Miss. Sheena. S.L. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude to Smt. L. Girija devi, Assistant Professor, Department of Agronomy, College of Agriculture, Vellayani and Chairman of the Advisory Committee for her valuable guidance, timely suggestions and constant encouragement throughout the course of this investigation and in the preparation of this thesis.

I am grateful to Dr. S. Janardhanan Pillai, Associate Professor and Head, Department of Agronomy for his whole hearted co-operation for the submission of the thesis.

I am grateful to Dr. V. Muraleedharan Nair, former Professor and Head, Department of Agronomy for his valuable suggestions in carrying out this investigation.

I am grateful to Dr. (Mrs.) V.L. Geethakumari, Associate Professor of Agronomy for the valuable suggestions rendered during the course of the programme and for the helpful comments she made during the final preparation of the thesis.

I express my sincere thanks to Dr. (Mrs.) K.S. Meenakumari, Assistant Professor, Department of Plant Pathology for her advice and help rendered at various stages of this investigation.

I extend my sincere thanks to Dr. (Mrs.) Elizabeth K. Cyriac and Dr. (Mrs.) Annamma George for their valuable help throughout the course of this investigation.

I owe my gratitude to all the members of Department of Agronomy, College of Agriculture, Vellayani for their whole hearted co-operation and assistance at various stages of this investigation.

My sincere thanks to Sri. C.E. Ajith Kumar, Programmer of Department of Agricultural statistics for the most valuable help in analysing the data.

I am grateful to Dr. Vijayaraghava kumar, Department of Agricultural statistics for the valuable help rendered during the analysis of data.

I am grateful to Sri. V.T. Bose, Farm Assistant, Department of Agronomy for the most valuable help rendered during the layout of experiment in the field.

I express my most sincere thanks to Sindhu and Jacob for their valuable help and assistance at various stages of this investigation and during the preparation of this thesis. I am thankful to Renjini, Renu, Anitha, Srinivas, Navaz, Sindhu K. Mathew and Sindhu. L. for their valuable help during the course of investigation.

I accord my sincere thanks to M/s. Athira Computers, Kesavadasapuram for neatly typing the thesis.

I am deeply indebted to my parents and brothers for the encouragement and inspiration given to me in making the programme a success.

I whole heartedly thank the Kerala Agricultural University for providing me necessary facilities for the conduct of this research.

Above all, I am thankful to God Almighty for blessing me for the successful completion of the thesis.

Sheena

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LIST OF ABBREVIATIONS

%	-	per cent
BCR	-	Benefit cost ratio
DAT	-	Days after transplanting
DMP	-	Dry matter production
Fig.	-	Figure
FYM	-	Farm yard manure
g	-	gram
GDD	-	Growing degree days
ha	-	hectare
HI	-	Harvest index
HTU	-	Heliothermal units
HUE	-	Heat unit efficiency
K	-	Potassium
Kg ha^{-1}	-	Kilogram per hectare
Kg	-	Kilogram
LAI	-	Leaf area index
m	-	metre
m^2	-	square metre
N	-	Nitrogen
^oC	-	Degree Celsius
P	-	Phosphorus
PTU	-	Photothermal units
t	-	tonnes

INTRODUCTION

1. INTRODUCTION

India is one of the major rice producing countries in South-East Asia. The leading aromatic fine quality rice (*Oryza sativa* L.) in the world trade popularly known as basmati is traditionally grown in the north and north-western parts of Indian sub continent for centuries. It is generally cultivated in the temperate region or where day temperature remains 20-22^{0}C during the winter. Scented rice cultivation is very less when compared to the total rice cultivation in India. It occupies 0.7 mha (15 per cent of total area under rice) in our country with an average productivity of 0.85 t ha^{-1} (Chandra *et al.*, 1997). At present India produces about 0.7 to 0.8 mt of milled basmati rice. About 60-70 per cent of the produce is exported every year mainly to Saudi Arabia, UAE, Kuwait, UK, Russia and USA.

Traditional basmati varieties posses excellent aroma and quality but their level of productivity is quite low. With the release of semi dwarf scented rice varieties, the optimum planting time had to be determined to exploit their grain yield potential while still maintaining grain quality (Singh *et al.*, 1995). The maximum productivity has been reported to be achieved by planting the crop at the optimum time at any specific location which may vary from variety to variety (Babu, 1987).

The productivity and quality of the aromatic rices depend on the environmental condition of the area where they are grown and the crop management practices followed to grow the crop. Quality traits of aromatic rices are known to be highly influenced by temperature, particularly at the time of flowering, grain filling and maturity. It is accepted that aroma formation in grain is enhanced at lower temperature during the grain filling stage (Rohilla *et al.*, 2000). Though the photoperiod insensitive varieties can be grown throughout the year irrespective of the season, their growth and yield largely depend upon various weather factors like rainfall, temperature, solar radiation and relative humidity that prevail during the growing season. Maximum yield is possible only when the crop experiences a suitable combination of these factors in optimum range. Hence the time of planting and prevailing weather conditions play a major role in the final yield of rice. At present in Kerala there is no information available with respect to the integrated influence of weather components in growth and yield of basmati rice. So the proposed study forms the first study of this type and has been taken with the following objectives.

To find out the best time of planting for getting maximum yield for different varieties of basmati rice, to study the influence of various weather parameters on growth and yield, to prepare a crop weather diagram of the best variety, to study the incidence of pest and diseases in relation to weather parameters and to work out the economics of basmati rice cultivation

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Basmati rice is characterised by superfine slender grain, exquisite aroma, sweet taste, soft texture and extra elongation with a least breadth wise swelling on cooking. With the introduction of high yielding semi dwarf scented rice varieties the optimum planting time has to be determined to exploit their yield potential while still maintaining grain quality. Although the aromatic and other high quality rices have been cultivated for long time, the research attention on these rices has been given only in recent years. Also the focus has been mainly on the varietal development and productivity aspects. Information on the influence of management practices and environmental factors on the quality of rice are meagre.

2.1. EFFECT OF PLANTING TIME ON GROWTH PARAMETERS

Majid and Ahmed (1975) reported that plant height decreases with delay in transplanting. This was also reported by Latif (1982), Ali and Ismail (1982). According to Theetharappan and Palaniappan (1984) delay in planting date was found to decrease the height of the rice plant in short duration transplanted rainfed rice. A decrease in plant height, tiller production, leaf area index and dry matter production in medium duration low land rice entries with delayed sowing was also reported by Narayanaswamy (1984). Mandal *et al.* (1984) observed that leaf area index, crop growth rate and net assimilation rate decrease with increasing delay in planting date which adversely affected the productivity of rainfed rice. Jiang and Zhou (1987) reported a decrease in the number of tillers with delay in direct sown dryland rice. Ramaiah *et al.* (1987) revealed that among the three dates of planting at three levels of nitrogen on two rice varieties, transplanting during second crop season on 15th July increased the dry matter production, total number of tillers m^{-2} and uptake of nitrogen as compared to other dates of planting.

Trivedi and Kwatra (1987) studied the effect of date of transplanting on rice cv. Patel-85 and reported that the growth of the crop was significantly higher when planted on June 30th during first crop season. Sreelatha (1989) reported that early planting recorded taller plants and more number of tillers. Wang and Liu (1991) reported that delaying the sowing date resulted in reduced seedling emergence, leaf area index, dry matter accumulation per unit area and net assimilation rate in direct sown rainfed rice.

Jand *et al.* (1994) observed that delay in transplanting reduced the seedling dry matter in cv. PR106 and PR109 but gave an increase in Basmati 370. Dry matter production in the leaves decreased in all the three cultivars with the later transplanted date. According to Om *et al.* (1998) crop growth rate prior to panicle initiation stage was higher in July transplanted crop. Ramesh and Singh (1999) reported that IR-36 and Pusa basmati-1 have an earlier and longer tillering period compared to Basmati-370. Percentage of effective tillers was higher in low tillering cultivars than in high tillering one.

2.2 INFLUENCE OF PLANTING TIME ON DURATION OF GROWTH PERIODS

Palaniswamy *et al.* (1968) reported that September planting of rice cultivars Co-30 and Bhavani take least number of days for flowering compared to earlier planting. Ramdoss and Subramanian (1980) reported similar results. Reddy and Reddy (1986) observed that duration of crop was found to decrease with delay in planting of rainfed rice. Reddy and Reddy (1992) reported that number of days required for 50 per cent flowering and crop duration were decreased by delayed planting in rice variety Surekha grown under rainfed condition. Jand *et al.* (1995) reported that number of days and thermal units required from sowing to floral induction was greater with the earliest planting date and in cv. Basmati-370. Angrish and Dhiman (1999) reported that crop sown on mid May had a longer vegetative growth duration, accumulated more biomass and tended to flower at the same time as mid June planting. According to Aswathi and Pandey (2000) days to 50 per cent flowering for Pusa basmati-1 was 105 days and for Kasturi it was 104 days. Genotypes suitable for submerged condition had higher number of days to 50 per cent flowering.

2.3 EFFECT OF PLANTING TIME ON YIELD AND YIELD ATTRIBUTES

Ramdoss and Subramanian (1980) reported higher straw yield with delay in planting. An experiment was conducted in 1980 at Pattambi to study the effect of different dates of planting and consequent seasonal influence on the uptake of nutrients on the important medium duration and short duration rice varieties. All varieties gave maximum yield for sowing made in 3rd May during virippu season. During mundkan all varieties gave poor yields for nursery in the 2nd week of October. During Punja, Jyothi sowing in the last week of December had recorded the highest grain yield while for Triveni sowing on the last week of January produced maximum grain yield (RARS, 1981 annual report).

Reddy and Narayana (1981) reported that number of panicles, filled grains panicle^{-1}, panicle length, grain yield and straw yield decreases with delay in planting in rainfed rice. This was also reported by Narayanaswamy *et al.* (1982). Production ha^{-1} and harvest index were also lowest for late sown crop. Choudhary (1984) found that late planting reduced yield in long duration, medium duration and short duration varieties in a trial in which cultivars were sown on seven dates from 2nd April to 1st June. Akram *et al.* (1985) reported that early sowing gave higher grain yield. Early planting (during last week of August) of second crop gave maximum yield and delayed plantings were severely affected by pest attack (KAU, 1985 annual report).

Dhaliwal *et al.* (1986) reported decrease in head rice recovery under late transplanting appeared due to high amount of chalky kernals. Akram *et al.* (1987) reported that in rice cv. Kashmir basmati grown with four fertilizer rates and transplanted on 24^{th} May, 8^{th} June, 24^{th} June and 8^{th} July got the highest average yield when planted on 8^{th} June.

Kamalam and Havanagi (1987) reported that Jaya gave higher yield in early planting while IR 20 and Pragathi gave higher yield in late planting. Length of panicle and panicle weight $hill^{-1}$ were higher in early planting and planting time did not affect number of tillers $hill^{-1}$ and number of spikelets $panicle^{-1}$. Verma and Singh (1998) reported that delay in sowing reduced the gross and net returns which resulted in decreased benefit cost ratio. Similar findings have been reported by Gangwar and Sharma (1998), Pajankar *et al.* (1997) and Mahal *et al.* (1999).

Ashraf *et al.* (1989) reported a progressive decline in yield and yield attributes with delay in transplanting. Decrease in yield was partly the result of decrease in productive tillers $hill^{-1}$ and spikelets $panicle^{-1}$. Perumal (1989) reported that planting during last week of September at 15x10 cm spacing gave maximum productive tillers. Higher straw yield noticed in early planted crop and grain yield was highest in late planted crop.

Padmaja (1990) observed that delay in planting beyond July resulted in reduction in grain yield and was attributed to more number of non productive tillers contributing to more chaff and partly filled grains. Singh *et al.* (1991) found that timely sowing at the onset of monsoon cause a significant increase in panicle length, panicle number, percentage of filled grains and thousand grain weight. Sidhu *et al.* (1992) reported that Pusa basmati-1 over yielded Basmati-385 and Basmati-370 in its relative performance under different fertility levels. They reported that transplanting on 30^{th} June was most suitable in Punjab to realise maximum yield.

Amarjit *et al.* (1993) reported that early planting the crop on 10^{th} July increased root density, NPK uptake, head rice recovery along with significant increase in grain and straw yield. Singh *et al.* (1993) reported reduction in yield and yield attributes with delay in planting time. These findings are in conformity with those of Babu (1987), Om *et al.* (1993), Gohain and Saikia (1993).

Four scented basmati rice varieties HKR-228, Pusa basmati-1, Kasturi and Basmati-370 transplanted on 5^{th} July, 15^{th} July, 25^{th} July and 4^{th} August, irrespective of variety, planting on 25^{th} July gave higher grain yield. Variety Kasturi recorded higher grain yield compared to other varieties irrespective of date of planting (CRRI, 1994 annual report).

Decreased grain yield with delay in planting was reported by Dhiman *et al.* (1995). Rao *et al.* (1996) reported that when scented rice varieties were transplanted after 15 July there was significant yield reduction. This finding was also reported by Singh *et al.* (1993), Thakur *et al.* (1996), Singh *et al.* (1997), Dhiman *et al.* (1997). Decrease in grain yield and yield attributes with delay in transplanting was reported by Singh *et al.* (1997) and Choudhary *et al.* (1998).

Bali and Uppal (1999) reported that early transplanting on 10^{th} July resulted in high root density and significantly increased the yield over late transplanting. Singh *et al.* (1999) reported that dwarf scented varieties showed better performance from mid December to mid January sowing. Rao *et al.* (2000) reported that delaying the planting time to end of July significantly reduced the mean grain yield.

2.4 EFFECT OF WEATHER PARAMETERS ON VEGETATIVE PHASE

During the vegetative growth period high humidity (70 to 80 per cent) and a temperature range of 25^{0}C to 35^{0}C are favourable for proper growth and development.

2.4.1 Rainfall

Chandler (1963) observed that many rice varieties respond better to nitrogen in dry season than in wet season. Chatterjee (1970) has made observations on tillering in a number of rice varieties and found that in rainy season, tillering is continued up to 42-45 days whereas in dry season it is 50-55 days. Sreenivasan and Banerjee (1978) observed that additional rainfall above the normal exerts negative influence during sowing, tillering and flowering stages of rice at Aduthurai. The rate of crop development and amount of rainfall normally expected during various phenological stages differs greatly with time of planting. Early planting lengthens the vegetative phase and shortens the grainfill phase while the reverse situation occurs at a late planting time (Neild *et al.*, 1983). According to Krishnakumar (1986) in NE monsoon season duration up to 50 per cent flowering and ripening period were negatively correlated with minimum temperature. Length of rainy season determines the duration of rice varieties (Sastri, 1986). The optimum value of total rainfall during the active growth phase was ascertained by Choudhary and Gore (1991) as 1000 mm. Gupta *et al.* (2000) observed that rice yields were significantly correlated with quantum of rainfall, length of rainy season and number of rainy days. Overall productivity of rainfed rice was unstable due to frequent fluctuations in the amount of rainfall, number of rainy days and duration of rainy season.

2.4.2 Temperature

Growth duration is considered important when associated with sowing time. The duration of growth of a rice cultivar determines its specific adaptability to the crop season in a given location. Kembuchetty (1978) reported a decrease in dry matter production when night temperature during vegetative phase was lesser. Advanced tiller emergence with high temperature was reported by Nagi (1968). Vergara *et al.* (1970) showed that minimum air temperature has the best negative correlation with growth duration. Choudhary and Ghildyal (1970) showed that tiller development is greately accelerated at 32/20°C day/night temperature. A deviation of 5°C to the lower side of 32/20°C more adversely affect the tiller development than a similar deviation to the higher side. Rao *et al.* (1971) reported that saturation vapour pressure deficit and maximum temperature are the two principal factors exerting maximum influence on evaporation. Owen (1971) reported that high temperature in general shortened the growth duration of rice plant. Kim *et al.* (1973) reported an increase in height and dry weight of plant at 20°C. Rajagopalan *et al.* (1973) observed a highly significant negative correlation between temperature during growth period and growth duration at Coimbatore where growth period coincide with low temperature during winter months. Sreedharan (1975) reported that the duration of vegetative phase is more correlated to soil-water interphase temperature than the minimum air temperature during this phase. Biswas *et al.* (1975) noticed that exposure to low temperature during active vegetative period can extend the time of flowering. Extended vegetative growth due to low temperature was also reported by Kang and Heu (1976), Chaudhary and Sodhi (1979). Temperature regime greatly affects the duration of rice growth (Datta, 1981; Yoshida, 1981).

Lin (1976) reported an increased production of ineffective tillers with high temperature. Chae *et al.* (1980) reported that dry weight and nutrient uptake of plants are affected more by temperature of growing medium than air temperature.

Jain *et al.* (1980) reported that above average maximum daily temperature is beneficial during vegetative and ripening stage and detrimental during lag vegetative stage of the crop. Shankar and Gupta (1981) observed a significant negative correlation between height of the crop and maximum, minimum and mean temperature and rainfall. Singh *et al.* (1984) observed an increase in water temperature of 2-3°C in continuous flow submergence which contributed to increased tillering, panicle size and grain number. Krishnakumar and Subramanian (1991) opined that progressive decrease in plant height with delay in planting was due to low minimum temperature and increase in sunshine hours.

2.4.3 Solar radiation

Sreenivasan and Banerjee (1978) reported that at Aduthurai, sunshine during flowering is highly favourable for enhanced production whereas at Coimbatore sunshine in the week prior to transplanting and the two week period coinciding with the grand period of elongation are not conducive for better yield. Low light intensity up to flowering in kharif imposed a ceiling on tillering and reduced dry matter production as compared to rabi (Venkateswarlu *et al.*, 1977). The crop shaded during vegetative phase were smaller and had a lower leaf area index and hence better light penetration during reproductive phase (Yoshida and Parao, 1976). Sreedharan and Vamadevan (1981) reported that LAI reduced to a great extend in plant shaded either from planting to panicle initiation or from flowering to harvest. Shankar and Gupta (1981) reported a significant positive correlation between height of two paddy varieties and duration of sunshine. Krishnakumar (1986) reported that plant height and leaf area index were seen to be negatively correlated with energy sources (solar radiation and sunshine hours) during the later phases of crop growth. Ghildyal and Kushevala (1987) made a detailed comparison of rice variety M3 with Jaya and observed that at both maximum tillering and flowering stages absorption of radiation was more in Jaya due to larger leaf area and higher number of tiller plant^{-1}. They also found that during maximum tillering stage net radiation (7 to 8 a.m. period) in Jaya was approximately double than in M3 but those differences narrowed (30 per cent) during the peak radiation level (11 a.m to 12 noon). Dash and Rao (1990) studied the effect of low light stress on two high yielding dwarf and traditional tall varieties grown at graded levels of shading and found that cultivar Ptb-10 was more tolerant to low light stress.

2.4.5 Relative humidity

Ou (1973) reported that high humid weather during periods of congineal temperature when followed by bright weather, trigger many diseases. Sreedharan

(1975) reported that a relative humidity of 80-85 per cent is ideal for shoot and root growth.

2.4.6 Wind

Light wind is beneficial as it stirs the air and transport CO_2 to the canopy (Matsubayashi *et al.*, 1963). Suge and Takairin (1982) reported that wind increases ethylene production in rice and decrease gibberilic acid content in roots and shoots.

2.5 INFLUENCE OF WEATHER ON REPRODUCTIVE STAGE

2.5.1 Rainfall

Venkateswarlu *et al.* (1976) reported higher panicle number in rabi compared to kharif season thus being responsible for high yields in the former. Rice yields were significantly correlated with quantum of rainfall, length of rainy season and number of rainy days. Overall productivity of rainfed rice was unstable due to frequent fluctuations in the amount of rainfall, number of rainy days and duration of rainy season. This was reported by Gupta *et al.* (2000).

2.5.2 Temperature

Datta and Zarate (1970) observed a significant correlation between yield and maximum temperature over the 45 days before maturity. Satake and Yoshida (1978) reported that high temperature induces sterility in rice and heading time is the most sensitive stage to high temperature. Low temperature during maximum tillering stage produced more panicles. This was reported by Osada *et al.* (1973).

During the reproductive stage within a temperature range of $22^{o}C$ to $31^{o}C$ spikelet number $plant^{-1}$ increases as the temperature drops (Yoshida, 1973). He also suggests that optimum temperature for rice shifts from high to low as the growth advances from vegetative to reproductive stages. Huda *et al.* (1975) found that higher maximum and minimum temperature during tillering, ear initiation and maturity depress the yield of rice. The rice plant is very sensitive to low temperature about 9 days before flowering and high temperature at flowering (Satake and Yoshida, 1978). Influence of temperature on sterility reported by Choudhary and Sodhi (1979). In the flowering period sterility is minimum (12-18 per cent) when the mean temperature is 27-28^{0}C whereas it is maximum (36 per cent) when mean temperature is above 36^{0}C. Yoshida (1981) observed a 13 day delay in flowering for each degree drop in temperature between 24^{0}C and 21^{0}C in IR-26. Maithy and Mahapatra (1988) reported that late and early planting reduced the yield perhaps due to ill effects of temperature. According to Samui (1999) maximum and minimum temperature followed by hours of bright sunshine played the most significant role towards higher rice production in India. Optimum values of maximum and minimum temperature were found to be 29-32^{0}C and 21-25^{0}C respectively. Yau (2000) also reported that an increase in temperature would reduce yields.

Beena and Balachandran (2001) reported that optimum temperature and increased sunshine hours with effective radiation which prevailed especially at the flowering stages of rabi season might have favoured an increase in photosynthesis and higher grain yield.

2.5.3 Solar radiation

Influence of light on panicle production and grain filling are reported by Yoshida (1972), Osada *et al.* (1973). Wada *et al.* (1973) and Yoshida and Parao (1976) reported that solar radiation and temperature during the reproductive stage (before flowering) have the greatest influence on rice yield because they determine the number of spikelets m^{-2}.

IRRI (1974) field studies revealed that there was a high positive correlation of grain number m^{-2} with solar radiation during 25 days before flowering. Stansel (1975) found that the most critical sunlight requiring period to be the 42 days centered around the heading stage. Nayak *et al.* (1979) reported that under low light intensity translocation of photosynthates to panicles is reduced. Amount of solar energy received from as early as panicle initiation until crop maturation was found important by Datta (1981) for the accumulation of dry matter during that period. Vergara and Chang (1985) reported that flowering in rice is delayed or completely inhibited when exposed to continuous long days. Angrish (1998) reported that under natural day length conditions basmati rice appear to get reproductively induced towards mid August onwards when the inductive day lengths of 13 hours and below are obtained.

2.5.4 Wind

Datta and Zarate (1970) reported that strong winds occuring after heading cause severe lodging and shattering in some varieties. Viswambaran *et al.* (1989) observed that strong winds reduces boundary layer resistance and increase the photosynthetic efficiency.

2.6 INFLUENCE OF WEATHER ON RIPENING STAGE

2.6.1 Temperature

Choudhary and Ghildyal (1970) reported beneficial effect of temperature regime 32/20^{0}C on yield characteristics such as number of spikelets panicle^{-1}, minimum sterility, thousand grain weight and grain yield. Boerma (1974) reported that at low temperature translocation of photosynthates to grain takes place at a slower rate and thus maturity period get delayed. Experiment at IRRI (1980) showed that a temperature range of 15-23^{0}C appears to be optimum for normal grain growth in all varieties of rice tested. Below and above this optimum temperature range grain weight lowered in all the varieties. Krishnakumar (1986) reported that ripening period is negatively correlated with minimum temperature of that period.

2.6.2 Rainfall

Sahu and Murty (1976) reported that dry matter production and grain yield are invariably lower by about 50 and 54 per cent respectively in wet season (July-October) than dry season (January-May). It was reported that at Pattambi at least one third of variability of virippu can be explained through fluctuations in monthly rainfall. Viswambharan *et al.* (1989) reported a negative correlation between yield and number of rainy days during maturity stage.

2.6.3 Solar radiation

Research at IRRI showed that the quantity of solar radiation has got a profound influence on rice yield particularly during the last 30-45 days of ripening period. Rao and Deb (1974) and Sreedharan (1975) reported that yield attributes such as panicles m^{-2} and grain yield recorded a positive correlation with solar energy during reproductive and ripening phases. Sahu *et al.* (1983), Nishiyama (1985) and Krishnakumar (1986) also reported same results.

2.6.4 Wind

Viswambharan *et al.* (1989) reported that high wind especially during flowering and maturity stages of rice lead to poor yield due to high sterility of spikelet. They also reported a negative correlation between wind velocity and yield of rice.

2.7 INFLUENCE OF PLANTING TIME ON COOKING QUALITIES

Uppal and Bali (1997) found that bulk density of polished rice decreased with delay in transplanting. Chatterjee and Maithy (1981) reported that rice with high (>10%) protein content or a high gelatinization temperature (74°C or more) require more water and longer cooking time to produce a cooked rice. Dhaliwal *et al.* (1986) observed that organoleptic qualities diminishes due to late planting. Rice varieties with higher water uptake and volume expansion preferred to other varieties (Tomar, 1987). Chaubey *et al.* (1988) reported that elongation ratio of scented rice varieties was higher than nonscented varieties. A decrease in milling and cooking qualities of scented rice with early or late planting was reported by Ali *et al.* (1991). Bandyopadhay and Roy (1992) reported that the attributes of appearance, tenderness, flavour of cooked rice are the final criteria of cooking quality and determines the palatability or eating characteristics of cooked rice. Ali *et al.* (1993) observed that delaying harvesting to lower moisture content decreased head rice recovery but had little effect on milled rice or cooking quality. Consumers prefer scented rice due to its aroma and outstanding cooking qualities. Though the quality of milled rice was greatly influenced by production, harvesting and post-harvest operations, variety remained the most important one to realise high price in the market (Dinesh, 1995). According to Singh *et al.* (1995) maximum hulling (76.5 per cent) and head rice recovery (40.8 per cent) and highest kernal length (6.8 mm) were recorded for 4th August planting although grain yield declined with delayed planting. Maximum elongation ratio of 1.9 was recorded for 25th July planting. Aroma was strong under all planting dates. Late planting promoted significant improvements in grain quality characteristics but at the cost of slightly reducing grain yield. Rani *et al.* (1996) observed that strong preference exists for long grain aromatic rice in the middle eastern countries. Singh and Singh (1997) reported that Indian consumers value aroma most followed by elongation after cooking. Saikila *et al.* (1999) reported that consumers prefer long slender or medium long slender translucent grain with high milling recovery, intermediate gelatinization temperature and very good elongation.

2.8 INFLUENCE OF WEATHER PARAMETERS ON QUALITY OF BASMATI RICE

Quality traits of aromatic rices are known to be highly influenced by temperature particularly at the time of flowering, grain filling and maturity. Aroma formation in grain is enhanced at lower temperature during grain filling stage. Maximum grain elongation was observed at 25/21^{0}C day/night temperature during ripening (Kush *et al.*, 1979). Mann (1987) also reported a day/night temperature of 25/21^{0}C (relatively cooler temperature) during crop maturity for better retension of aroma. Cruz (1991) also reported that grain elongation is influenced by temperature at the time of ripening. Late planting coinciding with flowering and maturity in cooler days has reported to enhance grain quality but reduce grain yield in all aromatic rice (Singh *et al.*, 1995), Rao *et al.* (1996), Thakur *et al.* (1996) and Chandra *et al.* (1997). According to Meng and Zhou (1997) a mean daily temperature of 18^{0}C produced best quality rice.

2.9 INFLUENCE OF WEATHER ON PEST AND DISEASE INCIDENCE

Yoshida and Parao (1976) reported that weather conditions influence directly various growth and developmental stages of a crop and indirectly the incidence of pest and diseases. Saroja and Raju (1985) reported that feeding damage by rice bug (*Leptocorisa acuta*) was found to be lowest when planted on 30th January. Very early and very late rice crops were prone to panicle bug attack. Vidhyasekharan and Lewin (1986) reported that the period favourable for vector multiplication and RTV incidence is September-October. Uthamaswamy and Karuppachamy (1986) reported that incidence of rice gall midge was maximum when rice planted on 1st September during second crop season and incidence was less when planted in August or October. Suharto and Noch (1987) reported that leaf folder infestation was more in early planted crop than late planted crop. Singh (1988) reported that rice army worm reproduction was most affected by temperature. Temperature during March (12-32^{0}C) considerably reduced oviposition period (4-5 days) compared to December-January (10-11 days). Rao and Padhi (1988) found that rainfall was negatively correlated with yellow stem borer infestation. Monsoon and intermittant rains found to affect the population built up.

Singh *et al.* (1986) reported that sheath rot caused by *Sarocladium oryzae* is an important disease in rainfed low land rice especially in delayed planting. Dhal and Choudhary (1987) reported that sheath rot incidence was high in delayed planting due to low temperature accompanied by low relative humidity during reproductive stage. Vivekanandan *et al.* (1995) reported that when scented rice varieties were tested for reaction to *Helminthosporium oryzae* in the field the most resistant parents identified were ADT-39 and Pusa basmati-1. Dodan and Singh (1995) reported that basmati rice variety planted on July 10 had least incidence of blast and highest grain yield. Prasad and Rana (2002) indicated that the lower minimum temperature was found associated with blast disease of rice.

2.10 UPTAKE OF NUTRIENTS

Singhania and Singh (1991) reported enhanced uptake of N, P and K in rice with the integrated application of nutrients. Rao *et al.* (1993) found that the response of grain yield to N application in the wet season was up to 60 kg ha^{-1} and in the dry season up to 90 kg ha^{-1}. Rao (1995) reported an increase in grain yield with N application.

Babu (1996) observed higher N and P uptake by medium duration rice with the integration of higher fertilizer dose along with 10 t ha^{-1} FYM. Zhilin *et al.* (1997) reported that plant height increased significantly in Basmati-370 with N application compared to other cultivars. Thakur *et al.* (1997) reported an increase in grain yield with up to 90 kg N ha^{-1}. According to Deepa (1998) maximum K uptake in rice variety Kanchana was with the integration of 45:22.5:22.5 kg NPK ha^{-1} as chemical fertilizer and the same quantity through FYM. Behera (1998) observed a significantly linear increase in grain yield up to 90 kg N ha^{-1} and thereafter the increase in grain yield was marginal. Giri *et al.* (1999) reported the highest grain yield of 1865 kg ha^{-1} from 120:60:30 kg NPK ha^{-1} plus trace elements. According to Dutta *et al.* (1999) aroma intensity was higher with N application at 25 kg ha^{-1} and sowing during the third week of August. Sujathamma *et al.* (2001) recorded highest 'P' uptake with 25 per cent organic source substitution.

2.11 VARIETAL RESPONSE

Khan and Ali (1985) reported that basmati-370 required the least time for water absorption and cooking. Also volume expansion, elongation ratio and water absorption ratio were highest in Basmati-370. Akram *et al.* (1985) reported that scented rice variety Kashmir basmati recorded greater yield when transplanted on 8^{th} June and there was no effect on grain protein content due to different dates of planting. Deosarkar and Nerkar (1993) found that basmati-370 possess maximum cooking and eating qualities among the scented varieties. Arumugachamy *et al.* (1992) identified Pusa basmati-1 as superior variety and he used this as a donor for aromatic and quality rice improvement. An elongation ratio of 2.06 was recorded for Basmati-370 by Chikkalingaiah *et al.* (1977). Dhiman *et al.* (1995) reported that Haryana basmati established well to produce maximum grain yield when planted by 15 July in Haryana. Singh *et al.* (1997) reported that Pusa basmati-1 gave higher yield than Kasturi. Angrish (1998) reported that photosensitive Taraori basmati and Basmati-370 required a minimum of seven short days for photoperiod induction after completing a vegetative phase of 50 days. According to Subha (2000) Kharif season was found to be more favourable season for getting higher plant growth and grain yield for basmati-370. But aroma, milling percentage and hulling percentage were higher for rabi crop. Deka *et al.* (2000) recorded maximum starch digestibility for Pusa basmati-1.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

A field experiment was conducted in the wetlands of the Instructional Farm, College of Agriculture, Vellayani during Rabi season of 2001 for assessing the performance of basmati rice (*Oryza sativa* L.) varieties under different dates of planting.

3.1 MATERIALS

3.1.1 Experimental site

The investigation was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani situated 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 texture of the soil of experimental field is sandy clay which belongs to the taxonomical order oxisol. The physico-chemical properties of the soil are presented in Table 3.1.

3.1.3 Climate

The experimental site enjoys a humid tropical climate and receives a good amount of rainfall. The weather data during the crop period were collected from the Meteorological observatory attached to the College of Agriculture, Vellayani. Rainfall, mean maximum and minimum temperature, relative humidity, wind speed, sunshine hours and evaporation for the cropping period (10-10-2001 to 18-2-2002) are presented in the Appendix I and graphically presented in Fig. 1.

Table 3.1. Physico-chemical properties of the soil of the experimental site

Sl. No.	Parameters	Content (%)	Method used
A. Mechanical composition			
1.	Coarse sand	47.76	Bouyoucos hydrometer method (Bouyoucos, 1962)
2.	Fine sand	10.64	
3.	Silt	8.60	
4.	Clay	33.00	
B. Chemical composition			
1.	Available N (kg ha^{-1})	311.38 (Medium)	Alkaline permangnate method (Subbiah and Asija, 1956)
2.	Available P_2O_5 (kg ha^{-1})	28.644 (Medium)	Bray colorimetric method (Jackson, 1973)
3.	Available K_2O (kg ha^{-1})	188.63 (Medium)	Ammonium acetate method (Jackson, 1973)
4.	Organic carbon (%)	1.70 (High)	Walkely and Black rapid titration method (Jackson, 1973)
5.	Soil pH	5.4 (Acidic)	1:2.5 soil solution ratio using pH meter with glass electrode (Jackson, 1973).

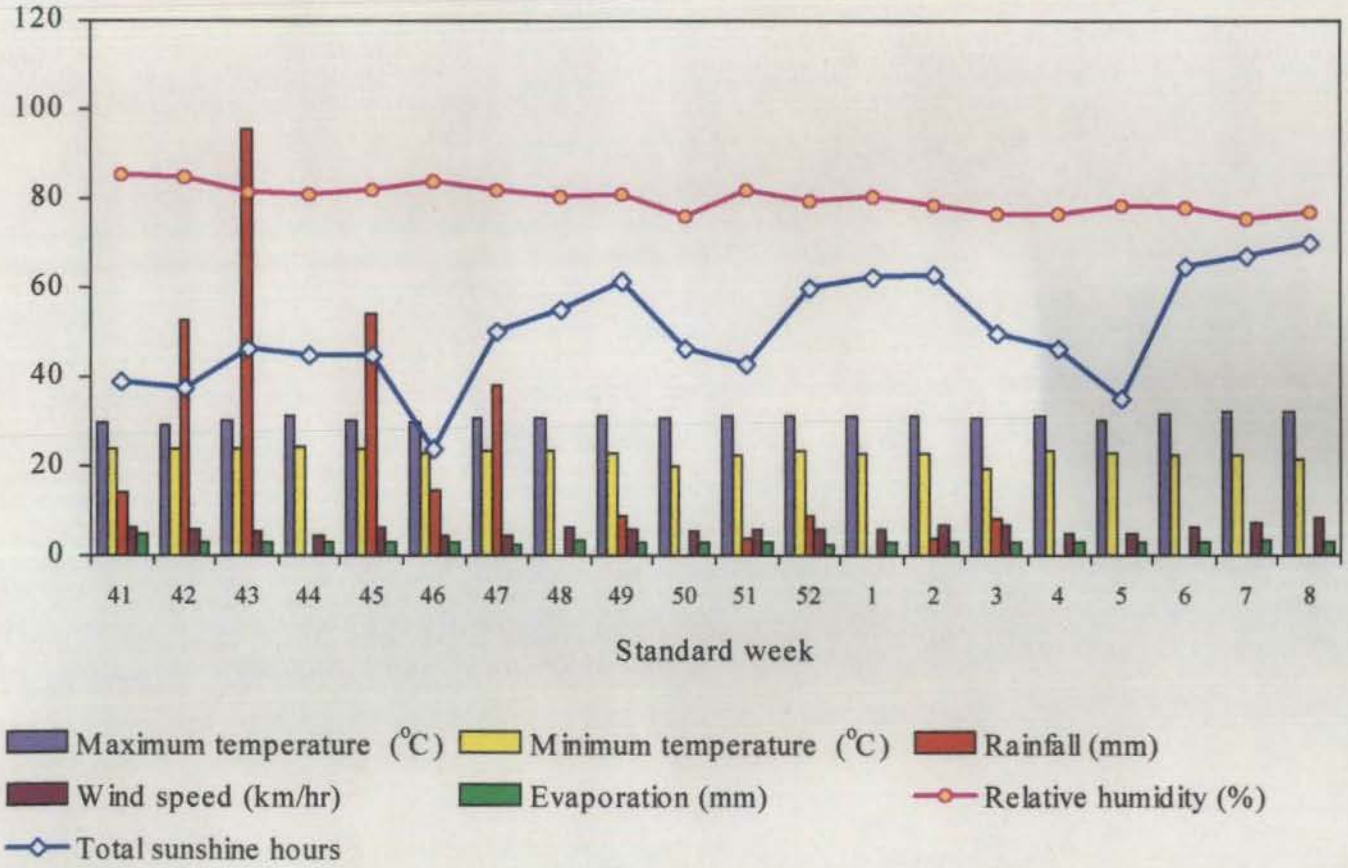


Fig. 1. Weather data during the entire crop growth period

3.1.4 Cropping season

The experiment was conducted during the second crop season (September - October to December - January) of 2001.

3.1.5 Cropping history of the field

The experimental area was under a bulk crop of rice during the previous season (Virippu).

3.1.6 Variety

Four basmati rice varieties tested in the investigation were Pusa basmati-1, Haryana basmati, Kasturi and Basmati-370.

Pusa basmati-1, a semi dwarf high yielding variety released from Indian Agricultural Research Institute, New Delhi is having a duration of 130-135 days susceptible to sheath blight and resistant to blast disease. It is having an yield potential of 4.5 t ha^{-1}. The seeds of Pusa basmati-1 was obtained from National Seeds Corporation (NSC), Thiruvananthapuram (Plate I).

Haryana basmati was released from Haryana Agricultural University, Rice Research Station (RRS), Kaul with a total duration of 140 days and is resistant to blast disease. The seeds of this variety was received from RRS, Kaul, Haryana (Plate II).

Kasturi, a high yielding variety released from Directorate of Rice Research (DRR), Hyderabad with a total duration of 125 days, possess excellent milling quality and is resistant to blast disease and tolerant to stem borer. The seeds were obtained from DRR, Hyderabad (Plate III).

Plate I. Variety - Pusa basmati-1

Plate II. Variety - Haryana basmati

Plate III. Variety - Kasturi

Plate IV. Variety - Basmati-370

Basmati-370, a photosensitive, tall, traditional variety with a total duration of 145-150 days and has an yield potential of 3 t ha^{-1}. The seeds were obtained from National Seeds Corporation (NSC), Thiruvananthapuram (Plate IV).

3.1.7 Fertilizers

Well decomposed and dried farmyard manure @ 5 t ha^{-1} was used for the experiment.

Urea (46% N), Mussurie rock phosphate (20% P_2O_5) and Muriate of Potash (60% K_2O) were used as the source of inorganic fertilizers. The fertilizer recommendation adopted was 90:45:45 kg NPK ha^{-1}.

3.2 METHODS

3.2.1 Design and Lay out

The experiment was laid out in strip plot design with three replications.

The lay out plan is given in Figure 2.

3.2.2 Treatments

The treatment consisted of combinations of four varieties and four dates of planting.

A. Varieties (v)

v_1 - Pusa basmati-1

v_2 - Haryana basmati

v_3 - Kasturi

v_4 - Basmati-370

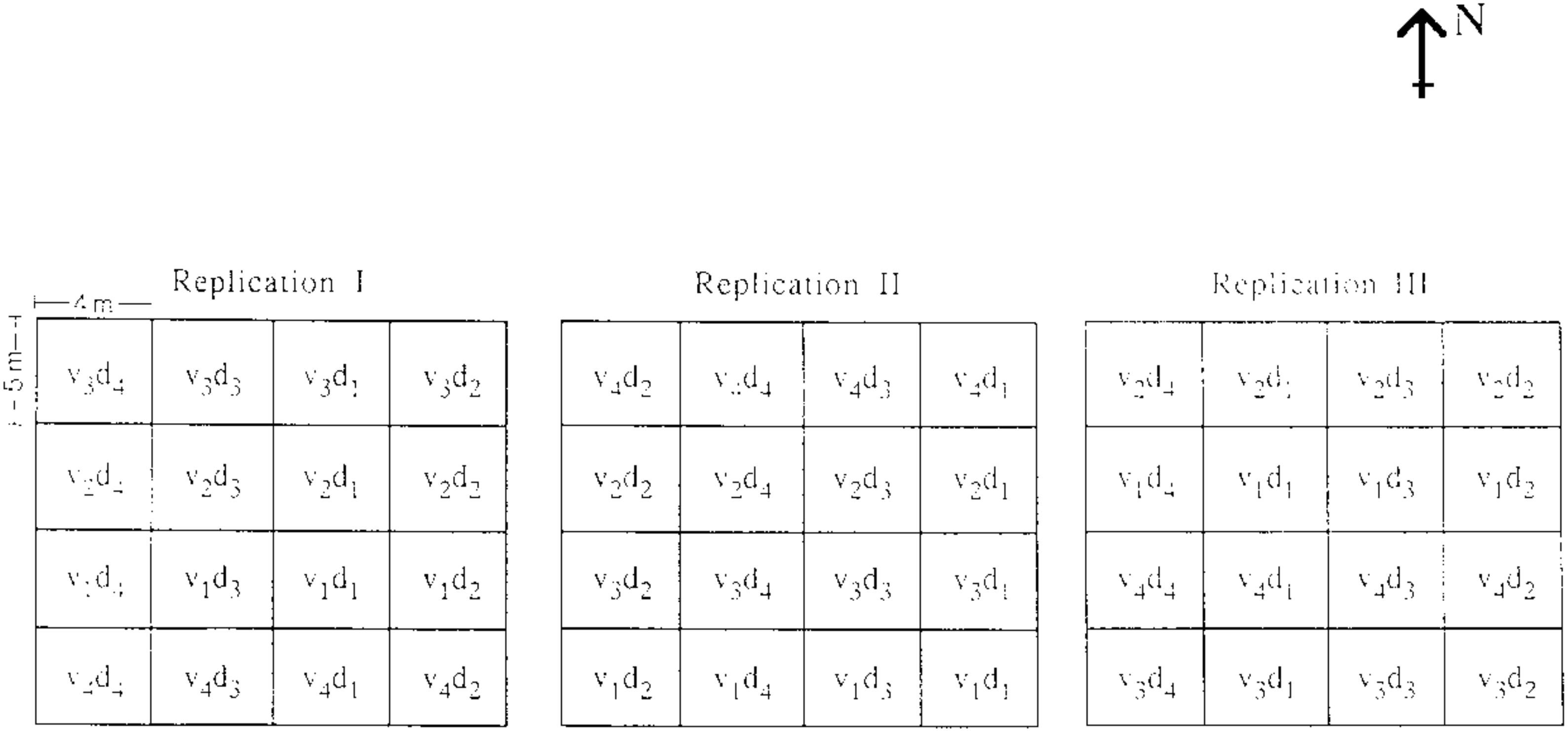


Fig. 2. Layout plan of the experiment

B. Date of planting (d)

d_1 October 10

d_2 October 23

d_3 - November 5

d_4 - November 18

C. Treatment combinations

T_1 - v_1d_1

T_2 - v_1d_2

T_3 - v_1d_3

T_4 - v_1d_4

T_5 - v_2d_1

T_6 - V_2d_2

T_7 - v_2d_3

T_8 - v_2d_4

T_9 - v_3d_1

T_{10} - v_3d_2

T_{11} - v_3d_3

T_{12} - v_3d_4

T_{13} - v_4d_1

T_{14} - v_4d_2

T_{15} v_4d_3

T_{16} - v_4d_4

Number of treatment combinations	-	16
Number of replications	-	3
Total number of plots	-	48
Gross plot size	-	5 x 4 m
Net plot size		4.6 x 3.8 m
Spacing	-	20 x 10 cm

3.3 CULTURAL OPERATIONS

3.3.1 Nursery

Four nurseries were raised to facilitate four dates of planting. Nursery beds of 1.2 m width, 15 cm height and convenient length with drainage channels in between were prepared and seeds were sown on these beds at fourteen days interval. First sowing was done on 22-09-2001, second on 3-10-2001, third on 14-10-2001 and fourth sowing on 31-10-2001.

3.3.2 Main field

The experimental area was ploughed, puddled and levelled. Weeds and stubbles were removed. Individual plots of size 5 x 4 m were laid out before transplanting.

3.3.3 Transplanting

Transplanting was done in a thin film of water in the field. Twenty days old seedlings were transplanted at a spacing of 20 x 10 cm. First transplanting was done on 10-10-2001, second transplanting on 23-10-2001, third transplanting on 5-11-2001 and fourth transplanting on 18-11-2001.

3.3.4 Application of manures and fertilizers

5 kg FYM plot^{-1} was applied uniformly and mixed well with the top soil before transplanting. Half N, full P and half K applied as basal. One fourth N applied at active tillering. The remaining one fourth N and half K were applied at seven days before panicle initiation stage.

3.3.5 Plant protection

Application of Sevin 50% WP was done against leaf roller and Hinosan 50% EC spraying was done against sheath blight incidence, after scoring for the disease.

3.3.6 Weeding

Two hand weedings were given for each plot on 20th and 40th DAT.

3.3.7 Plant sampling

Five plants were selected randomly from the net plot area and tagged as observational plants. Two rows from all sides were left as border rows.

3.3.8 Harvest

The crop was harvested at full maturity as and when the crop matures at different times according to the date of planting. The border and sampling rows were harvested separately. Net plot area of individual plots were harvested, threshed and weight of grain and straw were recorded.

3.4 OBSERVATIONS

3.4.1 Growth characters

3.4.1.1 Height of the plant at 30, 60 DAT and at harvest

The mean value of the height of five randomly selected observational plants from the net plot area was computed at 30 and 60 DAT and at harvest and expressed in cm. The height was measured from the base of the plant to the tip of top most leaf. At harvest, height was recorded from the base of the plant to the tip of the longest panicle and mean height was computed and expressed in centimeter.

3.4.1.2 Number of tillers hill^{-1} at 30, 60 DAT and at harvest

Number of tillers hill^{-1} from five randomly selected plants were counted at 30 and 60 DAT and at harvest.

3.4.1.3 Leaf area index at 30 and 60 DAT and at harvest

Leaf area index at 30 and 60 DAT and at harvest were calculated as per the method suggested by Gomez (1972).

Leaf area = L x W x K where 'L' is the length of leaf, 'W' is maximum width of leaf and 'K' is crop factor.

$$LAI = \frac{\text{Leaf area}}{\text{Land area}}$$

3.4.1.4 Number of days taken to panicle initiation

Duration in days from transplanting to panicle initiation was recorded.

3.4.1.5 Number of days taken from panicle initiation to flowering

Duration in days from panicle initiation to flowering was recorded.

3.4.1.6 Number of days taken from flowering to harvest

Duration in days from flowering to harvest was recorded.

3.4.1.7 Dry matter production

Dry matter production at harvest was recorded. Sample plants were uprooted, washed, sundried and oven dried at 80°C to constant weight and dry matter production expressed in kg ha^{-1}.

3.4.2 Yield and yield attributes

3.4.2.1 Number of productive tillers $hill^{-1}$

Five plants were selected randomly before harvest and mean value of number of productive tillers $hill^{-1}$ was recorded.

3.4.2.2 Number of spikelets $panicle^{-1}$

The number of grains in ten panicles collected randomly from the sampling area in each plot were counted and mean value was expressed.

3.4.2.3 Length of panicle

Length of panicle in cm from the neck to the tip of the panicle was measured.

3.4.2.4 Weight of panicle

Ten panicles were collected randomly, weighed individually and mean value was expressed in grams.

3.4.2.5 Number of filled grains $panicle^{-1}$

Spikelets from each panicle were removed and the number of filled grains were counted and mean value was recorded.

3.4.2.6 Thousand grain weight

Thousand grains from the cleaned produce from each plot were counted and weighed and mean value was expressed in grams.

3.4.2.7 Grain yield

Grains harvested from each net plot area were cleaned, dried to 13 per cent moisture content and weighed and expressed in kg ha^{-1}.

3.4.2.8 Straw yield

Straw obtained from each net plot area were dried properly under sun and weighed and expressed in kg ha^{-1}.

3.4.2.9 Harvest index

Harvest index was calculated using the formula,

$$\text{Harvest index, HI} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.4.3 Agrometeorological observations

a) Maximum temperature
b) Minimum temperature
c) Rainfall
d) Relative humidity
e) Bright sunshine hours
f) Wind speed
g) Pan evaporation

Daily reading of each meteorological parameter recorded in the Class B Agromet observatory attached to the College of Agriculture, Vellayani is used for the computation of the following crop-weather parameters.

3.4.3.1 Growing Degree Days (GDD)

Growing degree days (GDD), also called heat units, effective heat units or growth units, are a simple means of relating plant growth, development and maturity to air temperature (Vittum *et al.*, 1965). This is calculated by the formula (Iwata, 1984)

$$\text{Growing degree days GDD} = \sum_{i=1}^{n} \left(\frac{T_{max} + T_{min}}{2.0} - T_t \right)$$

where $\frac{T_{max} + T_{min}}{2.0}$ is the average daily temperature and T_t is the minimum threshold temperature for a crop. The minimum threshold temperature for rice is 10°C.

3.4.3.2 Photothermal units (PTU)

For different stages of growth, accumulated photothermal units were calculated by employing the formula of Major *et al.* (1975).

$$\text{Photothermal units PTU} = \text{Growing degree days x Mean day length}$$

3.4.3.3 Heliothermal units (HTU)

The product of degree days and hours of bright sunshine was termed as heliothermal units (Rajput, 1980; Sasthry and Chakravarthy, 1982).

$$\text{Heliothermal units HTU} = \text{GDD x No. of bright sunshine hours}$$

3.4.3.4 Heat unit efficiency (HUE)

To compare the performance of the variety taken under different dates of sowing with respect to utilization of heat in terms of day degree during the crop growth the Heat unit efficiency (HUE) was calculated as Growing degree days accumulating to produce unit amount of dry matter per unit area (Rajput, 1980).

$$\text{Heat unit efficiency (HUE)} = \frac{\text{DMP gm}^{-2}}{\text{GDD}}$$

3.4.3.5 Correlation studies

Correlation studies were also conducted wherever possible to find out the relationship between crop growth and yield and various meteorological parameters.

3.4.3.6 Crop weather diagram

Crop weather diagrams were prepared for the variety Kasturi which was found best and for the two planting dates 10^{th} October and 23^{rd} October by utilising the weather and crop data available during the respective periods.

3.4.4 Cooking quality

3.4.4.1 Optimum cooking time

Grain samples from the harvested lot of each net plot were collected and optimum cooking time was determined by the method suggested by Hirannaiah *et al.* (2001).

Milled rice was screened visually and whole sound grains were collected. 10 g samples were taken in a 250 ml beaker containing 150 ml slow boiling water and kept over an electric stove. The cooking time was determined using glass plate opaque-core method by withdrawing few grains periodically and pressing between two glass slides till no opaque portion or white core remained.

3.4.4.2 Elongation ratio

Elongation ratio was determined by the method suggested by Juliano and Peroz (1984). Elongation ratio of grains was expressed as the ratio of length of cooked rice kernels to raw kernels.

3.4.4.3 Volume expansion

Volume expansion was determined by cooking a definite amount of milled rice in uniform sized test tubes and the ratio of increase in volume was calculated.

3.4.4.4 Sensory evaluation scores for colour, aroma, taste, texture and overall acceptability

Grain samples were drawn from different treatments, cooked uniformly and subjected to organoleptic evaluation in which appearance, taste, texture, tenderness on touching, tenderness on chewing, aroma, elongation and overall acceptability were scored by ten panelists giving 0-5 scores. The data were subjected to statistical analysis.

3.4.5 Plant analysis

Sample plants collected from each plot at harvest were sun dried, oven dried to constant weight, ground, digested and nutrient content estimated. The N content (modified microkjeldahl method), P content (Vanado-Molybdo phosphoric yellow colour method) and K content (Flame photometer method) were estimated for plant samples from each plot separately (Jackson, 1973). Plant nutrient uptake was calculated by multiplying the nutrient content of the sample with the respective dry weight at harvest stage and expressed in kg ha^{-1}.

3.4.6 Incidence of pests and diseases

Scoring on sheath blight disease intensity was done using the score chart developed by International Rice Research Institute (IRRI), 1981.

Score	Description
0	No incidence
1	Lesions limited to lower one fourth of leaf area
3	Lesions present on lower half of leaf sheath area
5	Lesions present on more than half of lower leaf sheath area
7	Slight infection on upper leaves (flag and second leaf)
9	Lesions reaching top of tillers, severe infection on all leaves and some plants killed.

Disease index (DI) was calculated using the formula,

$$DI = \frac{\text{Sum of numerical ratings}}{\text{Total number of plants observed x Maximum disease grade}} \times 100$$

3.4.7 Economic analysis

3.4.7.1 Net returns

Net returns = Gross income - Cost of cultivation

3.4.7.2 Benefit cost ratio

Benefit - cost ratio was calculated using the formula

$$\text{BC ratio} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

3.4.8 Statistical analysis

The data recorded on plant growth characters, yield and yield attributes were subjected to analysis of variance technique as applied to Strip plot design (Cochran and Cox, 1965) and the significance was tested by F test. Wherever F test was significant, the critical difference (CD) is provided. The results and discussions are based on levels of significance.

RESULTS

with transplanting on November 18th (d_4) and was significantly superior to other combinations. Next highest value was recorded by v_4d_3 which was on par with v_3d_4 and v_4d_2. The lowest value of 51.67 cm was recorded by v_2d_1 which was on par with v_3d_1 and v_1d_1.

Table 4.1.a. Main effect of variety and date of planting on plant height

Treatments	Height of plant (cm)		
	30 DAT	60 DAT	Harvest
Varieties			
v_1	62.13	101.83	110.67
v_2	62.22	104.83	113.96
v_3	63.92	106.75	110.92
v_4	72.58	127.00	138.75
SE	0.65	1.26	0.92
CD	2.250	4.340	3.190
$F_{3,6}$	58.85**	83.08**	215.11**
Date of planting			
d_1	54.08	104.00	118.83
d_2	62.42	109.08	119.33
d_3	69.88	113.33	118.63
d_4	74.47	114.00	118.50
SE	0.53	0.85	0.76
CD	1.880	2.930	-
$F_{3,6}$	269.79**	29.78**	0.66

* Significant at 5 per cent ** Significant at 1 per cent

Table 4.1.b Interaction effect of variety and date of planting on plant height

Treatments	Height of plant (cm)		
	30 DAT	60 DAT	Harvest
v_1d_1	52.00	97.67	109.32
v_1d_2	56.50	98.33	111.66
v_1d_3	67.66	104.66	109.33
v_1d_4	72.83	106.67	112.33
v_2d_1	51.67	96.00	114.00
v_2d_2	61.67	107.33	117.67
v_2d_3	65.50	108.00	112.33
v_2d_4	70.03	108.00	111.83
v_3d_1	53.67	104.67	110.33
v_3d_2	56.67	106.00	109.33
v_3d_3	69.67	108.00	114.00
v_3d_4	75.67	108.33	110.00
v_4d_1	59.00	117.67	137.67
v_4d_2	79.83	124.67	138.67
v_4d_3	76.67	132.67	139.33
v_4d_4	79.83	133.00	139.33
SE	0.94	2.11	1.41
CD	2.810	-	-
$F_{9,18}$	10.42**	1.97	2.17

* Significant at 5 per cent ** Significant at 1 per cent

4.1.2. Tiller number hill^{-1}

Observations on tiller count were taken at 30 DAT, 60 DAT and at harvest. The number of tillers hill^{-1} as affected by treatments are presented in Tables 4.2.a and 4.2.b.

Table 4.2.a. Main effect of variety and date of planting on tiller number hill^{-1}

Treatments	Tiller number hill^{-1}		
	30 DAT	60 DAT	Harvest
Varieties			
v_1	9.15	12.17	9.96
v_2	11.82	11.88	11.00
v_3	8.63	12.33	11.33
v_4	10.47	12.08	12.08
SE	0.49	0.22	0.23
CD	1.680	-	0.790
$F_{3,6}$	8.60*	0.74	14.81*
Date of planting			
d_1	9.34	13.25	12.00
d_2	9.31	12.33	11.29
d_3	10.40	11.83	10.92
d_4	11.02	11.04	10.17
SE	0.31	0.41	0.22
CD	1.080	1.400	0.750
$F_{3,6}$	7.18*	5.16*	12.23**

* Significant at 5 per cent ** Significant at 1 per cent

Table 4.2.b. Interaction effect of variety and date of planting on tiller number hill^{-1}

Treatments	Tiller number hill^{-1}		
	30 DAT	60 DAT	Harvest
v_1d_1	8.24	13.00	10.50
v_1d_2	8.74	12.33	10.00
v_1d_3	9.38	12.00	9.83
v_1d_4	10.24	11.33	9.50
v_2d_1	11.45	13.33	12.33
v_2d_2	11.33	12.33	11.33
v_2d_3	12.00	11.67	11.0
v_2d_4	8.66	13.50	12.50
v_3d_1	8.00	12.50	12.50
v_3d_2	8.00	12.50	11.50
v_3d_3	8.67	12.00	10.83
v_3d_4	9.17	11.33	10.50
v_4d_1	9.00	13.17	12.67
v_4d_2	9.17	12.17	12.33
v_4d_3	11.57	11.67	12.00
v_4d_4	12.17	11.33	11.33
SE	0.45	0.59	0.37
CD	-	-	-
$F_{9,18}$	1.34	0.27	1.18

* Significant at 5 per cent ** Significant at 1 per cent

Varietal influence was significant at 30 DAT and at harvest. At 30 DAT maximum tiller number of 11.82 was recorded by Haryana basmati (v_2) and was significantly superior to v_1 and v_3 but on par with v_4. Lowest tiller count of 8.63 was recorded by Kasturi (v_3) which was on par with v_1. At harvest Basmati-370 (v_4) recorded the maximum tiller number of 12.08 which was significantly superior to v_2 and v_1 (9.15) but on par with v_3 (11.33). Lowest tiller count of 9.96 was recorded by Pusa basmati-1 (v_1)

Date of planting significantly influenced the tiller number at 30 DAT and at harvest. At 30 DAT d_4 recorded the maximum tiller number of 11.02 which was significantly superior to d_1 and d_2 whereas on par with d_3 (10.40). At 60 DAT and at harvest d_1 (transplanting on 10^{th} October) recorded the maximum tiller number of 13.25 and 12 respectively and was significantly superior to d_3 and d_4 whereas on par with d_2 (12.33 and 11.29 respectively).

Interaction effects were not significant at 30 DAT, 60 DAT and at harvest.

4.1.3. Leaf area index (LAI)

LAI at 30 DAT, 60 DAT and at harvest as influenced by varieties, date of planting and their interactions are presented in Tables 4.3.a and 4.3.b

Basmati-370 (v_4) recorded the maximum LAI of 4.67 at 30 DAT which was significantly superior to v_1 and v_3 but on par with v_2 (4.65). At 60 DAT and at harvest Haryana basmati (v_2) recorded the maximum LAI of 7.04 and 6.99 respectively and was significantly superior to v_4, v_3 and v_1. The lowest leaf area indices of 6.21 and 6.28 were recorded by Pusa basmati-1 (v_1) at 60 DAT and at harvest.

Table 4.3.a. Main effect of variety and date of planting on leaf area index (LAI)

Treatments	Leaf Area Index		
	30 DAT	60 DAT	Harvest
Varieties			
v_1	3.95	6.21	6.28
v_2	4.65	7.04	6.99
v_3	3.95	6.56	6.54
v_4	4.67	6.59	6.49
SE	0.12	0.08	0.09
CD	0.550	0.440	0.220
$F_{3,6}$	12.31**	17.12**	11.53**
Date of planting			
d_1	4.02	6.21	6.28
d_2	4.47	6.41	6.43
d_3	4.75	7.05	6.89
d_4	4.75	7.05	6.89
SE	0.10	0.12	0.06
CD	0.550	0.400	0.220
$F_{3,6}$	5.15*	10.05*	19.29**

* Significant at 5 per cent ** Significant at 1 per cent

Table 4.3.b. Interaction effect of variety and date of planting on leaf area index

Treatments	Leaf Area Index		
	30 DAT	60 DAT	Harvest
v_1d_1	3.55	5.73	6.06
v_1d_2	3.77	6.03	6.09
v_1d_3	3.95	6.18	6.20
v_1d_4	4.51	6.90	6.75
v_2d_1	5.20	6.91	6.87
v_2d_2	5.98	7.05	7.03
v_2d_3	3.65	7.70	6.98
v_2d_4	3.76	7.12	7.09
v_3d_1	3.34	6.06	6.04
v_3d_2	3.60	6.28	6.26
v_3d_3	3.69	6.80	6.92
v_3d_4	5.17	7.10	6.94
v_4d_1	3.99	6.14	6.12
v_4d_2	4.65	6.89	6.74
v_4d_3	4.65	6.89	6.74
v_4d_4	5.46	7.06	6.76
SE	0.29	0.13	0.16
CD	0.850	-	-
$F_{9,18}$	8.0**	2.16	1.67

* Significant at 5 per cent ** Significant at 1 per cent

Planting time also significantly influenced the LAI at 30 and 60 DAT and at harvest. At 30 and 60 DAT and at harvest d_4 recorded maximum leaf area indices of 4.73, 7.05 and 6.89 respectively which was significantly superior to d_1 and d_3 where as on par with d_2 (4.47, 6.41 and 6.43 respectively).

Interaction effects were significant only at 30 DAT. Haryana basmati planted on October 23 (v_2d_2) recorded the highest LAI of 5.97 which was on par with v_4d_4, v_2d_1 and v_3d_4. The lowest LAI of 3.33 was recorded by v_3d_1 which was on par with v_1d_2, v_2d_4, v_3d_3, v_2d_3, v_3d_2 and v_1d_1.

4.1.4. Number of days taken to panicle initiation (Table 4.4.a)

In general delayed planting took less number of days for panicle initiation. Among the varieties Haryana basmati took more number of days for panicle initiation in all dates of planting whereas kasturi took least number of days.

Table 4.4.a. Duration in days taken from transplanting to panicle initiation by basmati rice varieties under different dates of planting

Varieties	Dates of planting				
	d_1	d_2	d_3	d_4	Mean
v_1	58	65	44	44	52.75
v_2	52	58	42	46	49.50
v_3	53	63	45	44	51.25
v_4	53	62	40	43	49.50
Mean	54.00	62.00	42.75	44.25	

Haryana basmati planted on 10th October took about 65 days for panicle initiation whereas it took only 58 days when planted on 23rd October. Pusa basmati-1 planted on 10th October took 58 days for panicle initiation whereas 5th November planting took only 51 days. Basmati-370 planted on 10th October took about 44 days for panicle initiation whereas it took only 43 days when planted on 18th November. In the case of Kasturi, it took about 44 days for panicle initiation in October 10th planting and 40 days in November 5th and 18th planting.

4.1.5. Number of days taken from panicle initiation to flowering (Table 4.4.b)

Kasturi and Basmati-370 took about 18 days from panicle initiation to flowering when planted on 10th October whereas Pusa Basmati-1 took only 17 days and Haryana basmati took only 16 days. In all the varieties there was a slight reduction in the number of days from panicle initiation to flowering during October 23rd planting. Pusa basmati-1 took less number of days (14) from panicle initiation to flowering when planted on 23rd October. Haryana basmati took the least number of days (6) when planted on 18th November. Basmati-370 took least number of days (16) in 23rd October planting.

Table 4.4.b. Number of days from panicle initiation to flowering for basmati rice varieties under different dates of planting

Varieties	Dates of planting				
	d_1	d_2	d_3	d_4	Mean
v_1	17	16	18	18	17.25
v_2	14	10	14	16	13.50
v_3	17	8	15	20	15.00
v_4	11	6	15	19	12.75
Mean	14.75	10.00	15.50	18.50	

Table 4.4.c. Number of days from flowering to harvest for basmati rice varieties under different dates of planting

Varieties	Dates of planting				
	d_1	d_2	d_3	d_4	Mean
v_1	24	22	34	34	28.50
v_2	24	23	34	29	27.50
v_3	21	23	35	32	27.75
v_4	31	26	40	33	32.25
Mean	25.00	23.50	37.75	32.00	

Table 4.4.d. Total duration taken by basmati rice varieties under different dates of planting

Varieties	Dates of planting				
	d_1	d_2	d_3	d_4	Mean
v_1	119	123	116	116	118.50
v_2	110	111	110	101	108.00
v_3	114	112	115	114	113.75
v_4	115	114	115	115	114.75
Mean	114.50	115.00	114.00	111.50	

4.1.6. Days taken from flowering to harvest (Table 4.4.c)

Among the varieties Kasturi took more number of days for maturity whereas Haryana basmati and Pusa basmati-1 took less number of days. Haryana basmati planted on 10th October took about 22 days for maturity whereas the delayed planting in November 18th increased the period of maturity upto 26 days. In the case of Pusa basmati-1 it took about 24 days for maturity for October 10th as well as October 23rd planting and the days increased to 26 when planted on 5th November. Kasturi took 34 days when planted on 10th October whereas it took only 29 days when planted on 23rd October.

4.1.7. Dry matter production (DMP)

The DMP at harvest as influenced by varieties and date of planting and their interaction effects are presented in Tables 4.5.a and 4.5.b.

Maximum DMP of 10958.67 kg ha^{-1} was recorded by Basmati-370 (v_4) which was significantly superior to v_2, v_3 and v_1. The lowest DMP of 6350.00 kg ha^{-1} was recorded for Pusa basmati-1 (v_1).

Planting time also significantly influenced the DMP. Maximum DMP of 9650 kg ha^{-1} was recorded by d_1 (transplanting on 10th October) and was significantly superior to d_3 and d_4 whereas on par with d_2 (9029.38 kg ha^{-1}). The lowest DMP of 7528.54 kg ha^{-1} was recorded by d_4 (transplanting on 18th November).

Among the interactions Basmati-370 planted on 10th October (v_4d_1) recorded maximum DMP of 13053.33 kg ha^{-1} which was significantly superior to the next highest (10600 kg ha^{-1}) recorded by v_4d_2. But v_4d_2 was on par with v_4d_3, v_3d_1, v_2d_1, v_2d_2, v_4d_4 and v_2d_3. The lowest DMP of 4356.67 kg ha^{-1} was recorded by v_1d_4 which was on par with v_1d_1 (4600 kg ha^{-1}).

Table 4.5.a. Main effect of variety and date of planting on dry matter production, number of productive tillers^{-1}, panicle length and panicle weight

Treatments	DMP (kg ha^{-1})	Produtive tiller $hill^{-1}$	Pancile length (cm)	Pancile weight (g)
Varieties				
v_1	6350.00	8.22	28.58	2.02
v_2	9659.63	9.16	26.54	1.77
v_3	7905.83	9.37	28.79	2.08
v_4	10958.67	8.98	26.83	1.73
SE	250.79	0.23	0.60	0.03
CD	867.770	-	-	0.120
$F_{3,6}$	64.90**	4.57	3.80	25.13**
Date of planting				
d_1	9650.00	10.37	30.50	2.05
d_2	9029.38	9.02	27.88	1.94
d_3	8702.21	8.58	26.63	1.85
d_4	7528.54	7.77	25.75	1.76
SE	200.39	1.34	1.78	-
CD	693.350	1.340	1.780	-
$F_{3,6}$	19.76**	7.93*	16.12**	3.98

* Significant at 5 per cent ** Significant at 1 per cent

Table 4.5.b. Interaction effect of variety and date of planting on dry matter production, number of productive tillers $hill^{-1}$, panicle length and panicle weight

Treatments	DMP ($kg\ ha^{-1}$)	Productive tillers $hill^{-1}$	Panicle length (cm)	Panicle weight (g)
v_1d_1	4600.00	10.83	32.00	2.11
v_1d_2	8351.67	10.83	28.67	2.02
v_1d_3	8009.67	10.17	27.33	2.05
v_1d_4	4356.67	9.67	26.33	1.88
v_2d_1	10395.00	9.67	28.00	2.04
v_2d_2	9692.00	9.50	26.83	2.04
v_2d_3	9400.00	9.33	26.66	1.83
v_2d_4	9295.00	8.83	24.67	1.58
v_3d_1	10551.67	8.70	32.23	2.14
v_3d_2	7473.33	8.50	28.33	2.09
v_3d_3	6736.67	8.25	27.83	2.03
v_3d_4	6361.67	8.10	26.67	2.04
v_4d_1	13053.33	7.83	29.67	1.90
v_4d_2	10600.00	7.80	27.67	1.81
v_4d_3	10580.50	7.66	24.67	1.67
v_4d_4	9600.83	7.33	25.33	1.54
SE	744.10	0.54	0.71	0.11
CD	2214.810	-	-	-
$F_{9,16}$	4.28**	0.31	1.44	0.55

* Significant at 5 per cent ** Significant at 1 per cent

4.2 YIELD ATTRIBUTING CHARACTERS AND YIELD

4.2.1 Number of productive tillers hill^{-1}

The average number of productive tillers hill^{-1} as influenced by varieties, date of planting and their interactions are presented in Tables 4.5.a and 4.5.b.

Haryana basmati (v_2) recorded the maximum number of productive tillers of 9.375 and the lowest number of 8.22 was recorded by v_1 (Pusa basmati-1). Date of planting significantly influenced the number of productive tillers hill^{-1}. Transplanting on 10th October (d_1) recorded maximum number of productive tillers of 10.37 which was significantly superior to d_2, d_3 and d_4. The lowest number of productive tillers was recorded by d_4 (7.77) which was on par with d_3 and d_2 (8.58 and 9.02 respectively).

Interaction effects were not significant.

4.2.2 Length of panicle

The results on length of panicle as influenced by various treatments are presented in Tables 4.5.a. and 4.5.b. The varieties didn't differ significantly in panicle length. But planting time had significant influence and the maximum length of 30.5 cm was recorded by d_1 which was significantly superior to d_2, d_3 and d_4. The lowest value was recorded by d_4 (25.75 cm).

Interaction effects were not significant.

4.2.3 Weight of panicle

The mean weight of panicle as influenced by different factors and their interactions are presented in Tables 4.5.a. and 4.5.b.

Varietal difference has significant influence on weight of panicle. Kasturi (v_3) recorded the highest panicle weight of 2.08 g which was significantly superior to v_2 and v_4 whereas on par with v_1 (2.02). Lowest panicle weight was recorded by Basmati-370 (1.73 g). Planting time had no significant influence on panicle weight.

Interaction effects were not significant.

4.2.4 Number of spikelets panicle^{-1}

Number of spikelets panicle^{-1} as influenced by varieties, date of planting and their interactions are presented in Tables 4.6.a. and 4.6.b.

Among the varieties Haryana basmati (v_2) recorded maximum number of spikelets panicle^{-1} (119.33) which was significantly superior to v_1, v_3 and v_4. The lowest number of spikelets panicle^{-1} was recorded by Basmati-370 (84.08). Date of planting also significantly influenced the number of spikelets panicle^{-1}. Transplanting on 10th October (d_1) recorded maximum number of spikelets panicle^{-1} (115.083) which was significantly superior to d_2, d_3 and d_4. The lowest number of spikelets panicle^{-1} was recorded by d_4 (91.75).

Among the interactions Haryana basmati transplanted on 23rd October (v_2d_2) recorded the highest number of spikelets panicle^{-1} (140) and was significantly superior to other treatment combinations. Next highest value was recorded by v_2d_1 (126.67) which was on par with v_3d_1 and v_1d_1. The interaction effect was least noticed for the treatment combination v_4d_1 (77.33).

Table 4.6.a. Main effect of variety and date of planting on number of spikelets panicle^{-1}, number of filled grains panicle^{-1} and thousand grain weight

Treatments	No. of spikelets panicle^{-1}	No. of filled grains panicle^{-1}	Thousand grain weight (g)
Varieties			
v_1	99.08	81.83	19.81
v_2	119.33	103.00	22.68
v_3	113.50	95.42	26.35
v_4	84.08	70.00	23.87
SE	1.48	1.70	0.05
CD	5.120	5.890	0.180
$F_{3,6}$	113.44**	73.75**	2774.7**
Date of planting			
d_1	115.08	99.58	24.20
d_2	109.67	93.08	24.00
d_3	99.50	83.67	22.70
d_4	91.75	73.92	21.79
SE	1.45	1.62	0.06
CD	5.030	5.620	0.210
$F_{3,6}$	51.28**	47.54**	334.59**

* Significant at 5 per cent ** Significant at 1 per cent

Table 4.6.b. Interaction effect of variety and date of planting on number of spikelets panicle^{-1}, number of filled grains panicle^{-1} and thousand grain weight

Treatments	No. of spikelets panicle^{-1}	No. of filled grains panicle^{-1}	Thousand grain weight (g)
v_1d_1	120.33	103.00	20.56
v_1d_2	99.67	86.87	20.33
v_1d_3	91.00	70.00	19.93
v_1d_4	85.33	67.67	18.40
v_2d_1	126.67	113.33	23.90
v_2d_2	140.00	116.67	23.78
v_2d_3	113.00	71.00	22.36
v_2d_4	97.67	85.00	20.65
v_3d_1	126.33	105.67	27.07
v_3d_2	113.00	98.00	26.94
v_3d_3	108.00	95.00	25.93
v_3d_4	106.67	83.00	25.45
v_4d_1	87.00	76.33	25.28
v_4d_2	86.00	71.00	24.95
v_4d_3	86.00	72.67	22.58
v_4d_4	44.33	60.00	22.68
SE	3.86	4.46	0.11
CD	11.480	-	0.33
$F_{9,18}$	5.20**	2.08	21.68**

* Significant at 5 per cent ** Significant at 1 per cent

4.2.5 Number of filled grains panicle^{-1}

The mean number of filled grains panicle^{-1} as influenced by varieties, date of planting and their interactions are presented in Tables 4.6.a. and 4.6.b.

Among the varieties v_2 (Haryana basmati) recorded the maximum number of filled grains panicle^{-1} (103) which was significantly superior to v_1, v_3 and v_4. Basmati-370 recorded the lowest value (70). Among dates of planting d_1 (transplanting on 10th October) recorded the maximum number of filled grains panicle^{-1} (99.58) which was significantly superior to d_2, d_3 and d_4. The number of filled grains panicle^{-1} was lowest for d_4 (73.91).

Interaction effects were not significant.

4.2.6 Thousand grain weight

The thousand grain weight as influenced by various treatments and their combinations are presented in Tables 4.6.a. and 4.6.b.

Kasturi (v_3) recorded the highest thousand grain weight of 26.35 g which was significantly superior to v_1, v_2 and v_4. The variety Pusa basmati-1 recorded the lowest value (19.81 g). Among different planting time d_1 recorded the highest value of thousand grain weight (24.20 g) which was significantly superior to d_3 and d_4 whereas on par with d_2 (24.00 g).

Among the interactions, combination of Kasturi with October 10th planting (v_3d_1) recorded the highest thousand grain weight of 27.07 g which was on par with v_3d_2 (26.94 g). Pusa basmati-1 planted on 18th November recorded the lowest value (18.40 g).

4.2.7 Grain yield

The grain yield as influenced by different factors and their interactions are presented in Tables 4.7.a. and 4.7.b.

Varieties and date of planting significantly influenced the grain yield. Kasturi (v_3) recorded the highest grain yield (3.88 t ha^{-1}) which was on par with Haryana basmati (v_2) and significantly superior to v_1 and v_4. The variety Basmati-370 recorded the lowest grain yield of 2.76 t ha^{-1}. Among dates of planting, d_1 (October 10^{th} transplanting) recorded the highest grain yield (4.20 t ha^{-1}) followed by d_2 (3.50 t ha^{-1}). The lowest grain yield was recorded by d_4 (2.93 t ha^{-1}).

Interaction effects were not significant.

4.2.8 Straw yield

The straw yield as influenced by different factors and their interactions are presented in Tables 4.7.a. and 4.7.b.

There was no significant difference in straw yield among the varieties as well as the different dates of planting. Pusa basmati-1 (v_1) recorded the maximum straw yield of 10.13 t ha^{-1} while Kasturi (v_3) recorded the lowest straw yield of 7.87 t ha^{-1}.

4.2.9 Harvest index (HI)

The harvest index as influenced by different factors and their interactions are presented in Tables 4.7.a. and 4.7.b.

Table 4.7.a. Main effect of variety and date of planting on grain yield, straw yield and harvest index

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index
Varieties			
v_1	3.39	10.13	0.33
v_2	3.69	9.01	0.29
v_3	3.88	7.87	0.31
v_4	2.76	8.37	0.22
SE	0.07	1.73	0.23
CD	0.250	-	0.790
$F_{3,6}$	44.93**	0.32	19.76**
Date of planting			
d_1	4.20	8.12	0.32
d_2	3.50	8.31	0.30
d_3	3.09	11.26	0.26
d_4	2.93	4.69	0.27
SE	0.04	1.71	0.22
CD	0.140	-	0.760
$F_{3,6}$	192.29**	0.91	7.35*

* Significant at 5 per cent ** Significant at 1 per cent

Table 4.7.b. Interaction effect of variety and date of planting on grain yield, straw yield and harvest index

Treatments	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Harvest Index
v_1d_1	4.13	6.86	0.37
v_1d_2	3.55	6.82	0.34
v_1d_3	2.98	6.66	0.31
v_1d_4	2.92	6.57	0.31
v_2d_1	4.45	8.36	0.32
v_2d_2	4.13	9.67	0.30
v_2d_3	3.64	9.10	0.29
v_2d_4	3.31	8.91	0.27
v_3d_1	4.83	8.64	0.36
v_3d_2	3.73	7.94	0.32
v_3d_3	3.20	7.58	0.29
v_3d_4	3.03	7.33	0.29
v_4d_1	3.41	8.62	0.26
v_4d_2	2.60	8.81	0.24
v_4d_3	2.54	8.13	0.16
v_4d_4	2.49	7.95	0.24
SE	0.07	1.73	0.16
CD	-	-	-
$F_{9,18}$	1.19	0.96	0.54

Among the varieties v_3 (Kasturi) recorded the maximum harvest index of 0.31 which was significantly superior to v_2 and v_4 whereas on par with v_1 (0.33). Date of planting also significantly influenced the harvest index. Maximum harvest index of 0.32 was recorded by d_1 (October 10^{th}) which was on par with d_2 (0.30) but significantly superior to both d_3 and d_4 (0.26 and 0.27 respectively).

Interaction effects were not significant.

4.3 COOKING QUALITY

4.3.1 Cooking time

The cooking time as influenced by different factors and their interactions are presented in Tables 4.8.a. and 4.8.b.

Cooking time was significantly influenced by the varieties. Basmati-370 (v_4) took least time (12.66 minutes) for cooking while Haryana basmati (v_2) required more time (15.25 minutes) which was on par with v_1 (14.66 minutes).

Date of planting and treatment combinations had no significant influence on cooking time.

4.3.2 Elongation ratio

The elongation ratio as influenced by different factors and their interactions are presented in Tables 4.8.a. and 4.8.b.

Elongation ratio was significantly influenced by the varieties. Highest elongation ratio of 1.67 was recorded by Pusa basmati-1 (v_1) which was significantly superior to v_4 and v_2 whereas on par with v_3 (1.66).

Table 4.8.a. Main effect of variety and date of planting on cooking time, elongation ratio and volume expansion

Treatments	Cooking time	Elongation ratio	Volume expansion
Varieties			
v_1	14.66	1.67	4.36
v_2	15.25	1.49	2.63
v_3	14.16	1.66	3.65
v_4	12.66	1.57	3.00
SE	0.19	0.00	0.04
CD	0.690	0.030	0.150
$F_{3,6}$	30.65**	55.74**	316.50**
Date of planting			
d_1	13.66	1.62	3.41
d_2	14.33	1.60	3.47
d_3	14.25	1.60	3.38
d_4	14.50	1.57	3.38
SE	0.29	0.02	0.05
CD	-	-	-
$F_{3,6}$	1.52	1.02	0.77

* Significant at 5 per cent ** Significant at 1 per cent

Table 4.8.b. Interaction effect of variety and date of planting on cooking time, elongation ratio and volume expansion

Treatments	Cooking time	Elongation ratio	Volume expansion
v_1d_1	13.66	1.72	4.36
v_1d_2	15.00	1.64	4.40
v_1d_3	14.67	1.65	4.36
v_1d_4	15.33	1.65	4.33
v_2d_1	15.33	1.49	2.63
v_2d_2	15.33	1.50	2.78
v_2d_3	15.00	1.51	2.55
v_2d_4	15.33	1.48	2.55
v_3d_1	13.83	1.48	2.58
v_3d_2	13.33	1.66	3.62
v_3d_3	14.67	1.69	3.70
v_3d_4	14.33	1.68	3.62
v_4d_1	14.33	1.63	3.68
v_4d_2	12.33	1.60	3.03
v_4d_3	12.33	1.59	3.03
v_4d_4	13.00	1.58	3.00
SE	13.00	1.54	2.95
CD	-	-	-
$F_{9,18}$	1.71	1.34	0.37

Date of planting and interaction effects had no significant influence on elongation ratio.

4.3.3 Volume expansion

Volume expansion as influenced by different factors and their interactions are presented in Tables 4.8.a. and 4.8.b.

Among the varieties Pusa basmati-1 (v_1) recorded maximum volume expansion (4.36) which was significantly superior to v_2, v_3 and v_4. The volume expansion was lowest for Haryana basmati (2.63).

Different planting time and interaction effects had no significant influence on volume expansion.

4.3.4 Organoleptic test

Organoleptic qualities of basmati rice as influenced by varieties and date of planting are presented in Table 4.9.

Kasturi planted on 10^{th} October possess highest rank for appearance whereas lowest rank was obtained by Pusa basmati-1 and Haryana basmati.

Kasturi planted on 10^{th} October possess highest rank for cohesiveness whereas lowest ranking was obtained by Haryana basmati planted on 10^{th} October and 5^{th} November respectively.

Highest rank for tenderness on chewing was obtained for Kasturi planted on 10^{th} October and Pusa basmati planted on 23^{rd} October while Haryana basmati planted on 23^{rd} October and 18^{th} November received the lowest ranking.

Table 4.9. Organoleptic qualities of basmati rice varieties

Treatments	Rank means for quality characters							
	Appearance	Cohesiveness	Tenderness on touching	Tenderness on chewing	Taste	Aroma	Elongation	Overall acceptability
v_1d_1	68.50	98.90	89.30	110.40	92.50	87.60	108.30	90.10
v_1d_2	68.50	98.90	89.30	116.50	76.50	91.15	86.90	90.10
v_1d_3	68.50	98.90	73.50	98.10	76.50	79.30	86.90	82.20
v_1d_4	68.50	92.60	81.40	98.10	68.50	75.70	81.90	82.20
v_2d_1	68.50	20.60	82.10	98.10	68.50	60.10	39.10	43.00
v_2d_2	68.50	23.70	74.20	30.05	68.50	54.60	39.10	46.70
v_2d_3	68.50	20.60	73.50	33.40	60.50	54.60	35.00	43.00
v_2d_4	68.50	23.70	81.40	30.05	52.05	49.20	35.00	34.80
v_3d_1	124.50	111.50	89.30	116.50	108.5	109.40	108.30	121.30
v_3d_2	108.50	98.90	89.30	110.40	100.5	109.40	101.70	113.60
v_3d_3	92.50	98.90	73.50	98.10	84.50	103.00	101.70	97.95
v_3d_4	92.50	98.90	81.40	98.10	84.50	90.20	88.50	87.90
v_4d_1	84.50	105.20	81.40	79.70	92.50	85.70	100.10	90.10
v_4d_2	84.50	98.90	81.40	75.40	92.50	78.30	100.10	90.10
v_4d_3	76.50	98.90	73.50	75.40	84.50	79.30	91.00	82.25
v_4d_4	76.50	98.90	73.50	75.40	84.50	80.20	84.40	82.25
X^2	51.40*	113.40*	9.30	77.60*	24.40	28.60	61.27*	59.80*
Critital value	40.6	40.6	40.6	40.6	40.6	40.6	40.6	40.6

Highest rank for elongation was obtained for the varieties Pusa basmati-1 and Kasturi planted on 10th October respectively whereas lowest rank was for Haryana basmati planted on 18th November.

Kasturi planted on 10th October possess highest rank for overall acceptability followed by the varieties Pusa basmati-1 and basmati-370 planted on 10th October as well as 23rd October respectively.

There was no significant difference among the varieties regarding tenderness on touching, taste and aroma.

4.4 PLANT UPTAKE

4.4.1 Uptake of nitrogen

The mean N uptake as influenced by different factors and their interactions are presented in Tables 4.10.a. and 4.10.b.

N uptake was significantly influenced by the varieties. Haryana basmati (v_2) recorded the maximum plant uptake (87.30 kg ha^{-1}) followed by Basmati-370 (70.16 kg ha^{-1}). Pusa basmati-1 (v_1) recorded the lowest uptake of 65.04 kg ha^{-1}. Planting time also significantly influenced N uptake. Transplanting on 18th November (d_4) recorded the maximum uptake (88.99 kg ha^{-1}) which was significantly superior to d_1, d_2 and d_3. The lowest uptake of 59.30 kg ha^{-1} was recorded by d_1 (10th October planting).

Among the interactions, combination of Haryana basmati planted on 18th November (v_2d_4) recorded maximum uptake (107.67 kg ha^{-1}) and was significantly superior to all other treatment combinations. Pusa basmati-1 planted on 10th October (v_1d_1) recorded the lowest uptake of 53.15 kg ha^{-1} which was on par with v_3d_2, v_3d_1 and v_4d_1.

Table 4.10.a. Main effect of variety and date of planting on uptake of nitrogen, phosphorus and potassium, kg ha^{-1}

Treatments	Plant uptake (kg ha^{-1})		
	N	P_2O_5	K_2O
Varieties			
v_1	65.04	23.98	75.70
v_2	84.31	24.28	98.63
v_3	69.89	25.77	74.42
v_4	70.16	22.04	78.05
SE	1.07	0.78	2.21
CD	3.730	-	7.630
$F_{3,6}$	81.85**	3.83	26.59**
Date of planting			
d_1	59.30	23.81	86.88
d_2	63.40	27.29	85.09
d_3	80.71	22.82	79.34
d_4	88.99	22.18	75.48
SE	0.99	1.71	1.49
CD	3.450	-	5.160
$F_{3,6}$	199.81**	1.79	12.37**

* Significant at 5 per cent ** Significant at 1 per cent

Table 4.10.b. Interaction effect of variety and date of planting on uptake of nitrogen, phosphorus and potassium, kg ha^{-1}

Treatments	Plant uptake (kg ha^{-1})		
	N	P_2O_5	K_2O
v_1d_1	53.13	27.12	77.67
v_1d_2	58.89	25.26	76.46
v_1d_3	72.69	22.65	73.92
v_1d_4	75.47	20.87	74.74
v_2d_1	73.31	19.25	103.65
v_2d_2	77.17	27.12	103.86
v_2d_3	91.07	23.80	95.75
v_2d_4	107.67	26.86	91.23
v_3d_1	56.13	28.06	81.62
v_3d_2	56.81	30.82	78.12
v_3d_3	72.87	24.97	71.14
v_3d_4	93.75	19.24	63.77
v_4d_1	60.72	25.96	81.90
v_4d_2	60.72	25.96	81.90
v_4d_3	86.22	19.88	73.58
v_4d_4	79.08	21.67	72.15
SE	1.26	1.67	2.22
CD	4.370	5.800	-
$F_{9,18}$	15.37**	2.78*	1.41

* Significant at 5 per cent ** Significant at 1 per cent

4.4.2 Uptake of phosphorus

The uptake of phosphorus as influenced by different factors and their interactions are presented in Tables 4.10.a. and 4.10.b.

Variety and date of planting had no significant influence on phosphorus uptake by the plant. Among the interactions, combination of Kasturi planted on 23rd October (v_3d_2) recorded maximum uptake (30.82 kg ha^{-1}) which was on par with v_3d_2, v_3d_1, v_1d_1, v_2d_2, v_2d_4, v_4d_2 and v_1d_2. Lowest uptake was recorded by v_3d_4 (19.24 kg ha^{-1}) which was on par with all the other treatment combinations.

4.4.3 Uptake of potassium

The uptake of potassium as influenced by different factors and their interactions are presented in Tables 4.10.a. and 4.10.b.

Potassium uptake was significantly influenced by varieties and dates of planting. Among the varieties v_2 (Haryana basmati) recorded maximum uptake of 98.62 kg ha^{-1} which was significantly superior to v_1, v_3 and v_4. The variety Kasturi (v_3) recorded the lowest uptake of 74.41 kg ha^{-1} which was on par with v_4 and v_1.

Among dates of planting d_1 recorded maximum uptake of 86.88 kg ha^{-1} which was significantly superior to d_3 and d_4 whereas on par with d_2 (85.09 kg ha^{-1}).

Interaction effects were not significant.

4.5 INCIDENCE OF PESTS AND DISEASES

Scoring on sheath blight disease was done based on the score chart given by International Rice Research Institute, 1981 and is presented in Tables 4.11.a. and 4.11.b.

Table 4.11.a. Main effect of variety and date of planting on sheath blight disease

Treatments	Disease index	
Varieties		
v_1	41.70	(6.43)
v_2	5.29	(2.26)
v_3	9.65	(3.01)
v_4	6.41	(2.49)
SE	1.32	
CD	-	
$F_{3,6}$	172.23	
Date of planting		
d_1	19.43	(4.07)
d_2	17.40	(3.73)
d_3	14.12	(3.36)
d_4	12.11	(3.03)
SE	0.66	
CD	-	
$F_{3,6}$	24.6	

Table 4.11.b. Interaction effect of variety and date of planting on sheath blight disease

Treatments	Disease index	
v_1d_1	45.67	(6.74)
v_1d_2	47.05	(6.83)
v_1d_3	38.61	(2.20)
v_1d_4	35.49	(5.95)
v_2d_1	5.99	(2.41)
v_2d_2	4.21	(2.04)
v_2d_3	7.29	(2.67)
v_2d_4	3.71	(1.91)
v_3d_1	17.09	(4.13)
v_3d_2	10.57	(3.25)
v_3d_3	6.10	(2.46)
v_3d_4	4.86	(2.20)
v_4d_1	9.01	(2.99)
v_4d_2	7.77	(2.79)
v_4d_3	4.49	(2.12)
v_4d_4	4.40	(2.09)
SE	1.47	
CD	-	
$F_{9,18}$	3.00	

Among the varieties v_1 (Pusa basmati-1) showed highest disease incidence (41.70 %) whereas v_2 (Haryana basmati) recorded the least incidence (2.26 %). Disease infection was there in all the varieties irrespective of dates of planting.

Among the interactions, Pusa basmati-1 planted on 23rd October (v_1d_1) recorded maximum disease intensity of 47.05 per cent and the least by v_2d_4 (3.71 %).

4.6 COST OF CULTIVATION

4.6.1 Net returns

Net returns as affected by various factors and their interactions are presented in Tables 4.12.a. and 4.12.b.

Maximum net return of Rs. 43,421 was obtained for Kasturi (v_3) which was significantly superior to v_4 and v_1 whereas on par with v_2 (Rs. 42,749). Date of planting also significantly influenced the net returns. Maximum net return of Rs. 55,632 was obtained for planting on 10th October (d_1) whereas d_4 obtained Rs. 26675.84 which was on par with d_3 (Rs. 3,087).

4.6.2 Benefit cost ratio (BCR)

The data pertaining to the mean values of benefit-cost ratio as influenced by different treatments and their interactions are presented in Tables 4.12.a and 4.12.b.

The variety Kasturi (v_3) gave the highest benefit-cost ratio of 2.01 which was significantly superior to v_1 and v_4 whereas on par with v_2 (1.98). Basmati-370 recorded the lowest BCR of 1.66. Among different dates of planting d_1 recorded highest benefit-cost ratio of 2.30 which was significantly superior to d_2, d_3 and d_4. Lowest benefit cost ratio was recorded for d_4 (1.61) which was on par with d_3 (1.71).

Interaction effects were not significant.

Table 4.12.a. Main effect of variety and date of planting on net returns and BCR

Treatments	Net returns (Rs. ha^{-1})	BCR
Varieties		
v_1	36349.67	1.84
v_2	42749.58	1.98
v_3	43421.75	2.01
v_4	28732.84	1.66
SE	1777.61	0.04
CD	6150.620	0.130
$F_{3,6}$	14.81**	17.92**
Date of planting		
d_1	55632.00	2.30
d_2	38075.42	1.87
d_3	30870.59	1.71
d_4	26675.84	1.61
SE	27.61	0.03
CD	4523.750	0.100
$F_{3,6}$	95.54**	109.94**

* Significant at 5 per cent ** Significant at 1 per cent

Table 4.12.b. Interaction effect of variety and date of planting on net returns and BCR

Treatments	Net returns (Rs. ha^{-1})	BCR
v_1d_1	50886.67	2.17
v_1d_2	39509.00	1.91
v_1d_3	28525.67	1.66
v_1d_4	26479.34	1.61
v_2d_1	62665.00	2.52
v_2d_2	44724.67	2.03
v_2d_3	33501.67	1.77
v_2d_4	30109.00	1.69
v_3d_1	67517.66	2.56
v_3d_2	44004.67	1.98
v_3d_3	32781.67	1.74
v_3d_4	29389.00	1.66
v_4d_1	41466.67	1.95
v_4d_2	24063.34	1.55
v_4d_3	28675.34	1.65
v_4d_4	20726.00	1.42
SE	4008.60	0.09
CD	-	-
$F_{9,18}$	1.05	1.22

4.7 AGROMETEOROLOGICAL STUDIES

The tables presented in this part are not statistically analysed.

The maximum, minimum and mean values of various meteorological parameters recorded during the crop growth period of each variety at different dates of planting are presented in Tables 4.13.a, 4.13.b, 4.13.c and 4.13.d. The following crop-weather parameters were computed from the data.

4.7.1 Growing degree days (GDD)

The Growing degree days (GDD) required to attain each phenological phase by different varieties under different date of planting is presented in Table 4.14.

The duration of various phenophases with respect to varieties and planting dates showed wide variations (Fig. 3). The number of days taken for attainment of different phenological stages were largely in order $d_1 > d_4 > d_3 > d_2$. The most early sowing d_1 took longest time (119, 123, 116 and 116 days respectively) for attainment of maturity in Pusa basmati-1, Haryana basmati, Kasturi and Basmati-370 genotypes respectively (Table 4.4.d).

Degree-days based phenology

The GDD required to attain different phenological stages in basmati rice genotypes (Table 4.14) revealed that sowing date could have marked influence on degree days accumulated. For different planting dates GDD from planting to maturity ranged between 1487 to 1709°Cd, 1488 to 1605°Cd, 1317 to 1620°Cd and 1316 to 1620°Cd for Pusa basmati-1, Haryana basmati, Kasturi and Basmati-370 respectively.

Table 4.13.a. Maximum, minimum and mean values of weather parameters and grain yield at critical growth stages and whole growth period of basmati rice varieties planted on 10th October 2001

Character / stage of crop	Maximum temperature (°C)	Minimum temperature (°C)	Cumulative heat units °Cd	Accumulated heliothermal units (°Cd)	Bright sunshine hours	Rainfall (mm)	Relative humidity (%)	Wind (km hr^{-1})	Yield (t ha^{-1})
Vegetative									
Maximum	31.00	24.20	1064.55	7099.72	61.60	95.70	85.30	6.40	
Minimum	29.50	22.90	732.40	4654.06	23.80	8.60	80.30	4.60	
Mean	30.25	23.55	899.75	5670.47	42.70	55.15	2.90	5.51	
Reproductive									
Maximum	31.00	23.00	302.60	2812.49	61.60	8.60	82.00	5.70	
Minimum	30.60	2.00	195.75	856.95	42.70	3.70	76.20	5.40	
Mean	30.80	21.75	248.75	2224.76	51.80	3.70	79.75	5.80	
Maturity									
Maximum	31.40	23.50	585.37	4731.44	63.00	-	80.30	6.90	
Minimum	30.70	19.50	344.80	3518.53	49.70	-	76.60	5.70	
Mean	31.05	21.50	465.08	17698.53	56.35	-	78.70	6.28	
Whole growth									
Maximum	31.40	24.20	1645.5	13422.59	63.00	95.70	8530	6.90	4.83
Minimum	29.50	19.50	1601.6	11475.2	23.80	3.70	76.20	4.60	3.41
Mean	30.55	21.85	1623.55	12319.86	48.53	20.14	81.00	5.70	4.21

Table 4.13.b. Maximum, minimum and mean values of weather parameters and grain yield at critical growth stages and whole growth period of basmati rice varieties planted on 23rd October 2001

Character / stage of crop	Maximum temperature (°C)	Minimum temperature (°C)	Cumulative heat units °Cd	Accumulated heliothermal units (°Cd)	Bright sunshine hours	Rainfall (mm)	Relative humidity (%)	Wind (km hr^{-1})	Yield (t ha^{-1})
Vegetative									
Maximum	31.00	24.20	937.29	5325.56	61.60	95.70	84.10	6.30	
Minimum	29.70	20.00	680.94	4287.29	23.80	14.60	73.20	4.60	
Mean	30.35	22.10	805.12	4866.87	43.00	55.15	80.92	5.35	
Reproductive									
Maximum	31.00	23.50	273.30	2451.09	60.20	37.90	82.00	5.70	
Minimum	30.60	20.00	188.95	984.90	42.70	3.70	76.20	5.40	
Mean	30.80	21.75	230.13	1749.01	51.85	11.00	79.23	5.60	
Maturity									
Maximum	31.40	23.50	550.05	4776.84	63.00	8.60	80.30	6.90	
Minimum	30.70	19.50	294.10	2385.25	46.00	3.70	76.60	5.10	
Mean	31.05	21.50	422.17	3542.80	54.60	6.15	78.65	6.13	
Whole growth period									
Maximum	31.40	24.20	1424.09	11956.76	63.00	95.70	81.40	6.90	4.14
Minimum	29.70	19.50	1424.09	8076.07	23.80	3.70	76.20	4.60	2.60
Mean	30.55	21.85	1424.09	10158.68	49.80	15.92	80.09	5.72	3.50

Table 4.13.c. Maximum, minimum and mean values of weather parameters and grain yield at critical growth stages and whole growth period of basmati rice varieties planted on 5th November 2001

Character / stage of crop	Maximum temperature (°C)	Minimum temperature (°C)	Cumulative heat units °Cd	Accumulated heliothermal units (°Cd)	Bright sunshine hours	Rainfall (mm)	Relative humidity (%)	Wind (km hr^{-1})	Yield (t ha^{-1})
Vegetative									
Maximum	31.00	23.70	1021.40	5392.14	60.20	54.20	84.10	6.30	
Minimum	29.70	20.00	787.05	4562.47	23.80	3.70	76.20	4.60	
Mean	30.35	21.85	-	4967.09	42.20	115.30	80.86	5.53	
Reproductive									
Maximum	31.40	23.50	285.50	3115.31	63.00	8.30	82.00	6.80	
Minimum	31.00	22.90	188.95	1739.91	60.20	3.30	78.20	5.70	
Mean	31.20	23.20	-	2313.11	61.60	11.90	78.86	6.06	
Maturity									
Maximum	31.50	23.50	444.80	4111.22	63.00	-	78.40	6.90	
Minimum	30.20	19.50	312.00	1892.46	35.20	-	76.60	4.90	
Mean	30.85	21.50	-	2907.51	49.25	-	77.48	5.93	
Whole growth period									
Maximum	31.50	23.70	1585.5	12418.42	63.00	54.20	84.10	6.90	3.47
Minimum	29.70	19.50	1585.5	8572.14	23.80	3.70	76.20	4.60	2.55
Mean	30.60	21.60	1585.5	10187.72	50.49	9.09	79.64	5.70	3.04

Table 4.13.d. Maximum, minimum and mean values of weather parameters and grain yield at critical growth stages and whole growth period of basmati rice varieties planted on 18th November 2001

Character / stage of crop	Maximum temperature (°C)	Minimum temperature (°C)	Cumulative heat units °Cd	Accumulated heliothermal units (°Cd)	Bright sunshine hours	Rainfall (mm)	Relative humidity (%)	Wind (km hr^{-1})	Yield (t ha^{-1})
Vegetative									
Maximum	31.40	23.50	1077.20	7545.56	63.00	37.90	82.00	6.80	
Minimum	30.50	20.00	733.90	5400.13	42.70	3.70	76.20	4.60	
Mean	30.95	21.75	-	6383.49	53.00	28.91	79.96	5.74	
Reproductive									
Maximum	31.00	23.50	346.35	3998.50	63.00	8.3	78.40	6.90	
Minimum	30.70	19.50	276.80	1825.92	46.20	-	76.60	5.10	
Mean	30.85	21.50	-	3161.69	54.35	8.3	77.20	6.27	
Maturity									
Maximum	32.20	23.50	423.60	3640.39	70.20	-	78.30	8.30	
Minimum	30.20	20.00	137.30	1067.67	35.20	-	76.60	4.90	
Mean	31.20	21.75	-	2470.32	52.75	-	77.10	6.34	
Whole growth period									
Maximum	32.20	23.40	1607.61	11956.76	63.00	37.90	82.00	8.30	3.31
Minimum	29.70	19.50	1607.61	8076.07	35.20	3.70	76.20	4.60	2.48
Mean	30.95	21.45	1607.61	10158.68	53.25	4.87	79.05	5.93	2.93

Table 4.14.a. Growing degree days (GDD) required to attain various phenophases of basmati rice

Growth phase	Date of planting			
	d_1	d_2	d_3	d_4
Variety - Pusa basmati 1				
P_1	565.90	494.54	523.50	527.50
P_2	387.95	348.60	323.70	377.90
P_3	156.40	145.35	208.55	155.75
P_4	116.65	84.80	76.90	121.05
P_5	482.80	413.80	444.80	339.75
Variety - Haryana basmati				
P_1	616.35	510.99	541.15	527.50
P_2	448.20	566.21	480.25	549.70
P_3	110.70	118.70	104.90	172.55
P_4	85.05	70.25	137.15	117.55
P_5	344.80	362.30	323.10	240.31
Variety - Kasturi				
P_1	462.35	510.79	489.35	527.50
P_2	270.05	170.15	162.20	259.55
P_3	135.75	162.20	162.05	259.30
P_4	166.85	111.10	86.00	87.05
P_5	585.37	550.05	418.20	304.45
Variety - Basmati 370				
P_1	462.35	442.89	540.85	540.85
P_2	270.05	306.50	262.35	193.05
P_3	135.75	139.45	162.35	240.00
P_4	166.85	133.60	120.75	88.90
P_5	585.37	294.10	312.00	423.60

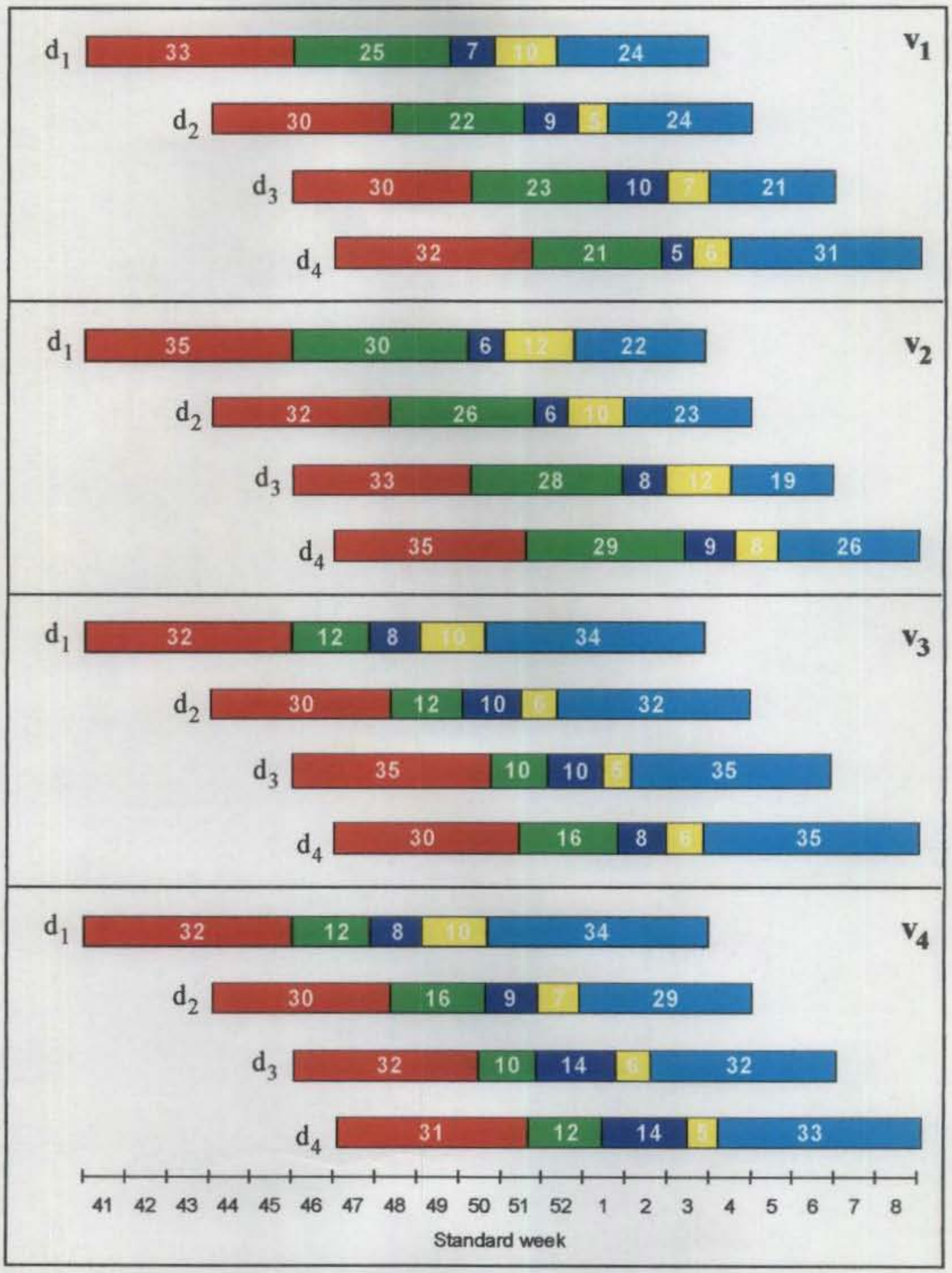
P_1 - Transplanting to maximum tillering

P_2 - Maximum tillering to panicle initiation

P_3 - Panicle initiation to 50 % flowering

P_4 - 50 % flowering to 100 % flowering

P_5 - Flowering to maturity



P_1 - Transplanting to maximum tillering

P_2 - Maximum tillering to panicle initiation

P_3 - Panicle initiation to 50% flowering

P_4 - 50% flowering to 100% flowering

P_5 - 100% flowering to maturity

v_1 - Pusa basmati-1 v_2 - Haryana basmati v_3 - Kasturi v_4 - Basmati-370

Fig. 3. Phenological calendar of basmati rice varieties

Table 4.14.b. Growing degree days (GDD) required by basmati rice varieties under different dates of planting for the whole growth period

Varieties	Dates of planting				
	d_1	d_2	d_3	d_4	Mean
v_1	1709.70	1487.09	1577.45	1521.95	1574.05
v_2	1605.10	1628.45	1586.55	1607.61	1601.93
v_3	1620.37	1504.29	1317.80	1437.85	1470.07
v_4	1620.37	1316.54	1398.30	1486.40	1455.40
Mean	1638.75	1484.09	1470.02	1513.70	

Regression models were developed for predicting timing of various phenophases with R^2 values of 98.7, 99.7, 99.0 and 99.0 for each genotype. These models were:

$$Y = -0.2607 + 16.688\ X$$

$$Y = -114.846 + 23.261\ X - 0.06084\ X^2$$

$$Y = -160.089 + 23.108\ X - 0.5703\ X^2$$

$$Y = -210.936 + 25.305\ X - 0.08067\ X^2$$

where, Y is predicted days to reach particular phenophase and X is GDD for particular phase of interest for Pusa basmati-1, Haryana basmati, Kasturi and Basmati-370 respectively.

Using these linearly fitted lines, the days taken to various phenophases could be predicted depending upon the minimum values of GDD required to reach that phase. The models for all four genotypes were tested by calculating the predicted values and were found normally fit for all genotypes (Table 4.15).

Table 4.15. Predicted calendar days required to attain various phenophases in basmati rice varieties

Variety	Actual days	Predicted days	Deviation from actual days
Pusa basmati-1			
P_1	31	31	0
P_2	23	25	2
P_3	8	5	-3
P_4	7	9	2
P_5	25	24	-1
Haryana basmati			
P_1	31	32	-1
P_2	28	27	-1
P_3	7	7	0
P_4	11	13	2
P_5	23	20	3
Kasturi			
P_1	31	30	1
P_2	13	14	-1
P_3	9	8	1
P_4	7	6	1
P_5	35	33	-2
Basmati-370			
P_1	32	32	0
P_2	12	11	-1
P_3	8	13	5
P_4	10	6	4
P_5	32	33	-1

4.7.2 Photothermal units (PTU)

For the different phenophases of growth, accumulated photothermal units were calculated by employing the formula

$$PTU = \text{Growing degree days} \times \text{Mean day length}$$

The photothermal units required by different varieties under different dates of planting is presented in Table 4.16.

Table 4.16. Photothermal units required by different varieties under different dates of planting

Varieties	Date of planting				
	d_1	d_2	d_3	d_4	Mean
Pusa basmati-1	20516.40	17845.08	18930.00	18263.40	18888.72
Haryana basmati	19261.20	17862.48	19038.60	18055.20	18554.37
Kasturi	19444.44	180.51.48	15813.60	17254.20	17640.9
Basmati-370	19444.44	15798.48	16779.60	17637.60	17415.03
Mean	19666.62	17389.38	17640.45	17802.6	

Among the varieties, Pusa basmati-1 took more photothermal units for maturity. The least photothermal units was taken up by Basmati-370 while Kasturi took slightly more photothermal units for maturity when compared to Basmati-370. Among the different planting time, October 23rd planting (d_2) took the least photothermal units while d_1 (October 10th) took maximum photothermal units.

4.7.3 Heliothermal units (HTU)

For the different phenophases of growth, accumulated heliothermal units were calculated by employing the formula

HTU = Growing degree days x No. of bright sunshine hours

The accumulated heliothermal units required by different varieties under different dates of planting is presented in Table 4.17. Among the varieties Pusa basmati-1 took more heliothermal units whereas Haryana basmati took the least. Among different dates of planting, October 10[th] planting (d_1) required the maximum heliothermal units whereas October 23[rd] planting (d_2) took the least.

Table 4.17. Heliothermal unit (HTU) required by different varieties under different dates of planting

Varieties	Date of planting				
	d_1	d_2	d_3	d_4	Mean
Pusa basmati 1	13422.59	11956.76	12418.42	14652.22	13112.49
Haryana basmati	11475.20	8076.07	8572.14	9267.58	9347.74
Kasturi	12190.83	11373.94	10137.3	12225.22	11481.82
Basmati-370	12190.83	9227.94	9623.01	11916.97	10739.69
Mean	12319.86	10158.67	10187.72	12015.49	

4.7.4 Heat unit efficiency (HUE)

The heat unit efficiency (HUE) was calculated by employing the formula

$$HUE = \frac{DMP\ gm^{-2}}{GDD}$$

The HUE as influenced by different varieties under different dates of planting is presented in Tables 4.18.a and 4.18.b.

Table 4.18.a. Effect of varieties and date of planting on heat unit efficiency (HUE)

Treatments	Heat unit efficiency
Variety	
v_1	0.24
v_2	0.33
v_3	0.29
v_4	0.41
$F_{3,6}$	19.76
SE	0.22
CD	-
Date of planting	
d_1	0.40
d_2	0.51
d_3	0.33
d_4	0.32
$F_{3,6}$	7.35
SE	0.22
CD	-

Table 4.18.b. Interaction effect of varieties and date of planting on heat unit efficiency (HUE)

Treatments	Heat unit efficiency
v_1d_1	0.28
v_1d_2	0.59
v_1d_3	0.51
v_1d_4	0.27
v_2d_1	0.63
v_2d_2	0.68
v_2d_3	0.59
v_2d_4	0.58
v_3d_1	0.66
v_3d_2	0.52
v_3d_3	0.42
v_3d_4	0.42
v_4d_1	0.69
v_4d_2	0.74
v_4d_3	0.67
v_4d_4	0.59

Basmati-370, a traditional variety recorded the highest HUE of 0.41 and the lowest HUE was recorded by Pusa basmati-1 (0.24).

Basmati varieties planted on 23rd October showed highest HUE of 0.51 while that planted on 18th November (d_4) showed the lowest HUE of 0.32.

Among the interactions the variety Basmati-370 (v_4) planted on 23rd October (d_2) recorded the highest HUE of 0.74.

4.7.5 Crop weather diagram

Crop weather diagram is a factual summary of the weekly progress of crop and the weather conditions experienced by it. The upper part of the diagram shows the weather conditions experienced by the crop. Crop data are presented in the lower part. Crop weather diagram for 10th October and 23rd October planting are presented in Fig. 4 and Fig. 5.

4.7.6 Correlation studies between weather parameters and growth characters and yield

The results of the correlation analysis conducted between meteorolgical parameters and crop growth and yield factors are presented in Tables 4.19.a, 4.19.b and 4.19.c respectively.

Vegetative phase

During the vegetative phase of the crop the mean values of maximum temperature, minimum temperature, total rainfall, sunshine hours, mean relative humidity, wind speed, cumulative degree days and accumulated heliothermal units were 30.34°C, 23.78°C, 27.78 mm, 403.4 hours, 82.96 %, 5.45 km hr^{-1}, 1064.55°Cd and 2958.21°Cd respectively. The mean maximum temperature ranged from 31°C to 29.7°C with a mean of 30.34°C while the minimum temperature ranged from 24.2°C to 23.1°C with a mean of 23.78°C. During this stage, plant height, tiller number and dry matter production showed a positive correlation with minimum temperature, rainfall, relative humidity and accumulated heliothermal units while a negative correlation was obtained with maximum temperature, sunshine hours, wind and cumulative degree days. Leaf area index showed a positive correlation with maximum temperature, sunshine hours, wind, cumulative degree days and accumulated heliothermal units while a

Crop : Basmati Rice | Variety : Kasturi
Year : 2001-2002 | DOP : 10-10-2001

State : Kerala
Station : Vellayani
Latitude : 8.5°N
Longitude : 76.9°E

Weather data

Months	October				November				December				January		
Standard weeks	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3
Weekly mean: Max. Temp.	30.0	29.5	30.3	31.0	30.4	29.7	30.5	30.5	31.0	30.6	31.0	31.0	31.4	31.0	30.7
Min. Temp.	23.7	24.0	24.0	24.2	23.7	23.1	23.4	23.2	22.9	20.0	22.3	23.5	23.0	22.9	19.5
Rainfall	14.2	52.6	95.7	Nil	54.2	14.6	37.9	Nil	8.6	Nil	3.7	8.6	Nil	3.7	8.3
R.H.	85.3	85.1	85.4	81.1	81.8	84.1	81.9	80.3	81.1	76.2	82.0	79.5	80.3	78.4	76.6
Sunshine hrs	39.2	39.2	37.8	46.2	44.8	44.8	23.8	50.4	55.3	61.6	46.2	42.7	60.2	62.3	63.0
Wind speed	6.4	5.7	5.4	4.6	6.3	4.6	4.6	6.3	5.7	5.4	5.7	5.7	5.7	6.8	6.9
Evaporation	4.8	3.0	3.0	3.1	2.8	3.1	2.4	3.3	2.9	2.7	3.1	2.4	2.9	2.7	2.8

Crop data

Date	Transplanting	10-10-'01
	Max. tillering	11-11-'01
	P.I.	23-11-'01
	Flowering	11-12-'01
	Harvest	14-01-'02
Duration from transplanting	Max. tillering	31
	P.I.	42
	Flowering	16
	Harvest	32

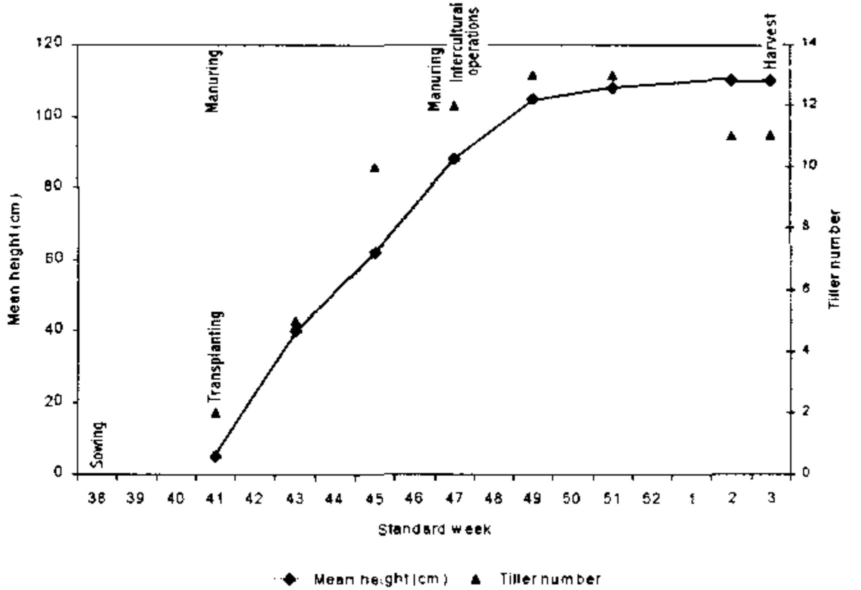
No. of tillers at	30 DAT	8.625
	60 DAT	12.250
	Harvest	11.330
Height of plants at	30 DAT	53.6 cm
	60 DAT	104.6 cm
	Harvest	110.3 cm
No. of productive tillers		10.8
No. of spikelets/panicle		126
Filled grains/panicle		105

Yield (kg ha^{-1})	
Grain	4832.10
Straw	8487.65
DMP	10551.60

1000 grain weight	27.06 g
Harvest Index	0.36

CROP NOTE / SPECIAL REMARKS

No major pests observed. Sheath blight incidence during reproductive stage.



Rotation : *Paddy / Paddy* Seed rate : 80 kg/ha (2 seedlings/hill) Spacing : 20 x 10 cm Manures : FYM @ 5 t/ha Urea : 109 kg Massuriphos : 250 kg MOP : 166 kg

Fig. 4. Crop weather diagram (10-10-2001)

Crop : Basmati Rice
Year : 2001-2002

Variety : Kasturi
DOP : 23-10-2001

State : Kerala
Station : Vellayani
Latitude : 8.5°N
Longitude : 76.9°E

Weather data

Months	October				November				December				January			
Standard weeks	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4
Weekly mean: Max. Temp.	30.0	29.5	30.3	31.0	30.4	29.7	30.5	30.5	31.0	30.6	31.0	31.0	31.4	31.0	30.7	31.0
Min. Temp.	23.7	24.0	24.0	24.2	23.7	23.1	23.4	23.2	22.9	20.0	22.3	23.5	23.0	22.9	19.5	23.5
Rainfall	14.2	52.6	95.7	Nil	54.2	14.6	37.9	Nil	8.6	Nil	3.7	8.6	Nil	3.7	8.3	Nil
R.H.	85.3	85.1	85.4	81.1	81.8	84.1	81.9	80.3	81.1	76.2	82.0	79.5	80.3	78.4	76.6	76.6
Sunshine hrs.	39.2	39.2	37.8	46.2	44.8	44.8	23.8	50.4	55.3	61.6	46.2	42.7	60.2	62.3	63.0	46.2
Wind speed	6.4	5.7	5.4	4.6	6.3	4.6	4.6	6.3	5.7	5.4	5.7	5.7	5.7	6.8	6.9	5.1
Evaporation	4.8	3.0	3.0	3.1	2.8	3.1	2.4	3.3	2.9	2.7	3.1	2.4	2.9	2.7	2.8	3.0

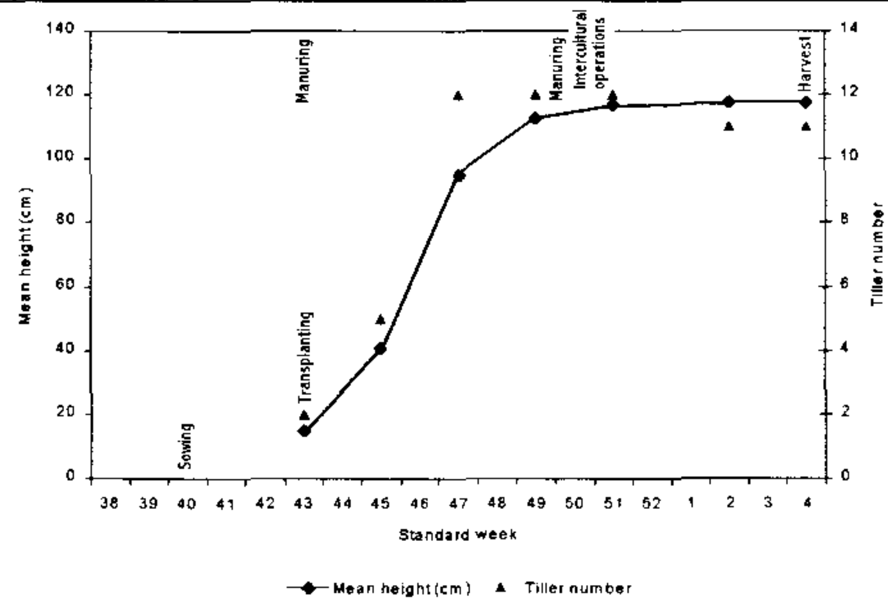
Crop data

Date	Transplanting	23-10-'01	No. of tillers at	30 DAT	8.00
	Max. tillering	22-11-'01		60 DAT	12.50
	P.I.	4-12-'01		Harvest	11.50
	Flowering	20-12-'01	Height of plants at	30 DAT	56.7 cm
	Harvest	21-01-'02		60 DAT	106.0 cm
				Harvest	109.3 cm
Duration from transplanting	Max. tillering	32	No. of productive tillers		8.5
	P.I.	12	No. of spikelets/panicle		113
	Flowering	18	Filled grains/panicle		98
	Harvest	34			

Yield ($kg\ ha^{-1}$)	
Grain	3730.00
Straw	7940.00
DMP	7473.33

1000 grain weight	26.94 g
Harvest Index	0.32

CROP NOTE / SPECIAL REMARKS
No major pests observed. Sheath blight incidence during reproductive stage.



Rotation : *Paddy / Paddy* Seed rate : 80 kg/ha (2 seedlings/hill) Spacing : 20 x 10 cm Manures : FYM @ 5 t/ha Urea : 109 kg Massuriphos : 250 kg MOP : 166 kg

Fig. 5. Crop weather diagram (23-10-2001)

negative correlation was obtained with minimum temperature, rainfall and sunshine hours. In the case of yield and yield attributing factors, a positive correlation was obtained with minimum temperature, rainfall, relative humidity, sunshine hours and cumulative heat units while maximum temperature, wind and accumulated heliothermal units showed a negative correlation.

Reproductive phase

During the reproductive phase the mean maximum temperature ranged from 31°C to 32.5°C while the minimum temperature ranged from 23.4°C to 20.0°C. The total rainfall and bright sunshine hours were 50.8 mm and 163.1 hours respectively. The mean maximum relative humidity ranged from 81.59% to 79.2% with a mean of 81% while wind speed ranged from 6.3 to 4.6 km hr^{-1} with a mean of 5.53 km hr^{-1}. The mean cumulative heat units and accumulated heliothermal units were 242.05°Cd and 3998°Cd respectively. During this stage, plant height, tiller number and dry matter production showed a positive correlation with rainfall, relative humidity and sunshine hours while a negative correlation was obtained with wind, maximum temperature, cumulative heat units and accumulated heliothermal units. Leaf area index showed a positive correlation with maximum temperature, relative humidity and wind while a negative correlation was obtained with minimum temperature, rainfall, sunshine hours, cumulative heat units and accumulated heliothermal units. In the case of yield and yield attributing characters, a positive correlation was obtained with rainfall, cumulative heat units and relative humidity. Panicle weight, filled grains $panicle^{-1}$ and thousand grain weight showed a negative correlation with maximum temperature, wind and accumulated heliothermal units while number of spikelets $panicle^{-1}$ and harvest index showed a positive correlation with maximum and minimum temperature. Harvest index showed a positive correlation with all the weather parameters except cumulative heat units.

Table 4.19.a. Correlation coefficients between growth characters and different meteorological parameters during different phenophases of basmati rice

Weather parameter	Stage of crop	Plant height	Tiller number	LAI	DMP
Maximum temperature					
	Vegetative	-0.12	-0.64**	+0.63**	-0.42
	Reproductive	-0.25	-0.58*	+0.45	-0.25
	Maturity	-0.08	+0.45	-0.33	-0.36
	Whole growth period	-0.28	-0.75**	-0.32	-0.34
Minimum temperature					
	Vegetative	+0.04	+0.61*	-0.76**	+0.26
	Reproductive	-0.03	+0.06	-0.04	-0.03
	Maturity	-0.13	+0.35	-0.05	-0.05
	Whole growth period	-0.30	+0.47	-0.09	+0.34
Rainfall	Vegetative	+0.03	+0.67**	-0.63**	+0.31
	Reproductive	+0.13	+0.54*	-0.51	+0.39
	Maturity	+0.001	-0.70**	+0.15	+0.58*
	Whole growth period	+0.12	-0.87**	+0.68	+0.33
Relative humidity	Vegetative	+0.13	+0.33	-0.65**	+0.15
	Reproductive	+0.26	+0.61*	+0.01	+0.10
	Maturity	+0.66**	-0.69**	+0.39	+0.53
	Whole growth period	+0.31	+0.33	-0.61	+0.33
Sunshine hours	Vegetative	-0.29	-0.36	+0.04	0.46
	Reproductive	+0.06	-0.18	-0.29	+0.04
	Maturity	+0.23	-0.25	-0.23	+0.39
	Whole growth period	+0.01	+0.58	-0.04	-0.35
Wind	Vegetative	-0.19	-0.35	+0.46	-0.44
	Reproductive	-0.05	-0.29	+0.24	-0.35
	Maturity	-0.57*	+0.29	-0.13	-0.37
	Whole growth period	-0.12	+0.82	-0.69	-0.27
CDD	Vegetative	-0.42	-0.45	+0.27	-0.13
	Reproductive	-0.21	-0.19	-0.16	0.20
	Maturity	-0.02	+0.45	-0.72	+0.08
	Whole growth period	-0.12	+0.31	-0.36	+0.02
AHTU	Vegetative	+0.81**	+0.38	+0.08	+0.34
	Reproductive	+0.84**	-0.44	-0.08	-0.36
	Maturity	+0.78**	+0.29	+0.04	+0.32
	Whole growth period	+0.82**	-0.41	-0.34	-0.35

* Significant at 5 per cent level ** Significant at 1 per cent level

Table 4.19.b. Correlation coefficients between duration and different meteorological parameters during different phenophases of basmati rice

Weather parameter	Stage of crop	Duration
Maximum temperature	Maximum tillering	-0.23
	Panicle initiation	+0.41
	50 % flowering	+0.27
	100 % flowering	+0.16
	Maturity	-0.31
Minimum temperature	Maximum tillering	+0.34
	Panicle initiation	-0.35
	50 % flowering	-0.36
	100 % flowering	+0.06
	Maturity	+0.35
Rainfall	Maximum tillering	+0.27
	Panicle initiation	-0.22
	50 % flowering	-0.11
	100 % flowering	+0.38
	Maturity	+0.14
Relative humidity	Maximum tillering	+0.29
	Panicle initiation	-0.21
	50 % flowering	-0.18
	100 % flowering	+0.05
	Maturity	+0.11
Sunshine hours	Maximum tillering	+0.11
	Panicle initiation	-0.59*
	50 % flowering	-0.5
	100 % flowering	-0.51*
	Maturity	+0.79**
Wind	Maximum tillering	+0.31
	Panicle initiation	+0.60**
	50 % flowering	-0.05
	100 % flowering	-0.05
	Maturity	-0.44
CDD	Maximum tillering	-0.15
	Panicle initiation	-0.03
	50 % flowering	-0.04
	100 % flowering	-0.18
	Maturity	+0.21

* Significant at 5 per cent level ** Significant at 1 per cent level

Table 4.19.c. Correlation coefficients between yield and yield attributing characters and different meteorological parameters during different phenophases of basmati rice

Weather parameter and Stage of crop	Panicle weight	Spikelets panicle⁻¹	Filled grains panicle⁻¹	Thousand grain weight	Harvest index	Yield
Maximum temperature						
Vegetative	-0.41	-0.42	-0.34	-0.34	-0.59	+0.11
Reproductive	-0.25	+0.06	-0.04	-0.42	-0.25	+0.47
Maturity	-0.36	-0.34	-0.37	-0.24	-0.37	-0.31
Whole growth period	+0.88**	+0.52*	+0.86**	+0.31	-0.69**	-0.35
Minimum temperature						
Vegetative	+0.52*	+0.23	+0.29	+0.43	+0.57*	+0.32
Reproductive	-0.03	+0.11	-0.07	+0.11	-0.19	+0.26
Maturity	+0.05	+9.26**	+0.27	-0.05	+0.51*	+0.34
Whole growth period	+0.53*	-0.01	-0.07	+0.35	+0.69**	+0.37
Rainfall						
Vegetative	+0.48	+0.01	-0.07	+0.35	+0.68	+0.40
Reproductive	+0.39	+0.18	+0.15	+0.45	+0.42	+0.89**
Maturity	+0.58*	+0.17	+0.26	+0.84**	+0.43	-0.49
Whole growth period	+0.53*	-0.56*	-0.48	+0.35	+0.69**	+0.80
Relative humidity						
Vegetative	+0.30	+0.31	+0.01	+0.27	+0.23	+0.41
Reproductive	+0.10	+0.33	+0.42	+0.64**	+0.34	+0.35
Maturity	+0.53*	+0.35	+0.41	+0.51*	+0.58*	+0.13
Whole growth period	+0.45	+0.73**	+0.54*	+0.33	+0.44	+0.04
Sunshine hours						
Vegetative	+0.09	+0.09	-0.96	-0.52*	+0.10	+0.23
Reproductive	+0.04	-0.48	-0.55*	-0.25	-0.19	+0.17
Maturity	+0.39	-0.22	-0.18	+0.33	-0.04	+0.79**
Whole growth period	+0.54*	+0.43	+0.45	+0.33	+0.73	+0.05
Wind						
Vegetative	+0.05	+0.05	-0.18	-0.05	0.29	0.22
Reproductive	-0.35	-0.14	-0.18	-0.36	0.19	+0.26
Maturity	-0.36	-0.04	-0.05	-0.32	-0.80**	-0.43
Whole growth period	-0.36	+0.58*	+0.51*	-0.27	-0.36	0.43
CDD						
Vegetative	-0.36	+0.52*	+0.14	+0.35	+0.34	+0.06
Reproductive	-0.25	+0.14	+0.11	-0.17	-0.04	0.05
Maturity	-0.16	+0.36	+0.29	+0.16	+0.40	0.26
Whole growth period	+0.13	+0.34	-0.03	+0.40	+00.13	0.43
AHTU						
Vegetative	-0.02	-0.18	-0.19	-0.53*	-0.09	0.34
Reproductive	-0.17	-0.49	-0.59*	-0.23	-0.36	+0.15
Maturity	-0.36	-0.34	-0.37	0.25	-0.37	0.34
Whole growth period	-0.03	-0.34	-0.68**	0.001	-0.04	+0.13

* Significant at 5 per cent level ** Significant at 1 per cent level

Ripening stage

During the maturity phase, the values of mean maximum and minimum temperature, total rainfall, total bright sunshine hours, average relative humidity, wind speed, cumulative heat units and accumulated heliothermal units were 30.83°C, 21.8°C, 2.67mm, 237.48 hours, 79.88%,5.86 km hr^{-1}, 505.5°Cd and 1067°Cd respectively. In this stage, plant height, dry matter production and leaf area index had a negative correlation with maximum and minimum temperatures and wind while a positive correlation was obtained with rainfall, relative humidity, sunshine hours and accumulated heliothermal units. Tiller production showed a positive correlation with maximum and minimum temperatures, wind, cumulative heat units and accumulated heliothermal units while a negative correlation was obtained with rainfall, relative humidity and sunshine hours. In the case of yield, minimum temperature, rainfall, relative humidity and cumulative heat units had positive correlation while maximum temperature, sunshine hours and wind showed a negative correlation with yield. All the yield attributing characters showed a negative correlation with maximum temperature, wind and accumulated heat units.

Whole growth period

The mean values of maximum and minimum temperature, total rainfall, total bright sunshine hours, average relative humidity, wind speed, cumulative heat units and accumulated heliothermal units were 30.57°C, 22.87°C, 302.1 mm, 679.42 hours, 81%, 5.7 km hr^{-1}, 1526.64°Cd and 4731°Cd respectively. All the growth parameters showed a negative correlation with maximum temperature while minimum temperature had a positive correlation with tiller number and dry matter production. Tiller production was negatively correlated with rainfall while other growh parameters were positively correlated with rainfall. Relative humidity had positive correlation with all growth characters except leaf area index. Tiller number and dry matter production showed a positive correlation with cumulative heat units while plant height showed a positive correlation with accumulated heliothermal units. Correlation analysis between weather parameters and yield and yield attributing characters revealed that minimum temperature, rainfall, sunshine hours and cumulative heat units had a strong positive correlation with yield while maximum temperature and accumulated heliothermal units had a strong negative correlation. Number of spikelets panicle^{-1}, filled grains panicle^{-1}, thousand grain weight and panicle weight had a positive correlation with maximum temperature and sunshine hours while a negative correlation was observed with minimum temperature and accumulated heliothermal units. Number of spikelets panicle^{-1} and filled grains panicle^{-1} had a negative relation with rainfall and minimum temperature while a positive correlation obtained with wind. Panicle weight and thousand grain weight also showed a negative correlation with wind while a positive correlation with rainfall and sunshine hours.

4.7.7 Correlation between duration and weather parameters

During transplanting to maximum tillering phase of crop growth (P_1) maximum temperature and cumulative degree days showed a negative correlation while a positive correlation was obtained with minimum temperature, rainfall, relative humidity, total number of bright sunshine hours and wind. From maximum tillering to panicle initiation stage (P_2), a positive correlation was obtained with maximum temperature and wind while a negative correlation was obtained with minimum temperature, rainfall, relative humidity, sunshine hours and cumulative heat units. From panicle initiation to 50 per cent flowering (P_3), a positive correlation was obtained with maximum temperature and cumulative heat units while a negative correlation was obtained with minimum temperature, rainfall, relative humidity, sunshine hours and wind. During the period from 50 per cent flowering to 100 per cent flowering (P_4) maximum temperature, minimum temperature, rainfall and relative humidity showed a positive correlation while a negative correlation was obtained with sunshine hours, wind and cumulative heat units. During maturity phase (P_5) a positive correlation was obtained with minimum temperature, rainfall, relative humidity, sunshine hours and cumulative heat units while a negative correlation was obtained with maximum temperature and wind.

4.7.8 Correlation studies between weather parameters and sheath blight intensity

Correlation coefficients between weather parameters and sheath blight intensity revealed that there was a positive correlation between disease incidence and maximum temperature, relative humidity and rainfall. A negative correlation was observed with minimum temperature, total bright sunshine hours and wind.

DISCUSSION

5. DISCUSSION

The results of the experiment conducted to study the performance of basmati rice (*Oryza sativa* L.) varieties under different dates of planting are discussed in this chapter.

5.1 GROWTH AND GROWTH CHARACTERS

The results presented in Table 4.1a (Fig. 6) showed that there was significant difference among the varieties with respect to plant height. Lowest height was recorded by Pusa basmati-1 which is a semi dwarf photo insensitive variety while Basmati-370, a tall photosensitive traditional variety registered the maximum height. But the variety is susceptible to lodging due to its tallness. This was also reported by Angrish (1991). Planting time also significantly influenced the plant height at 30 DAT and 60 DAT. The plant height showed a positive correlation with rainfall and relative humidity during all stages of crop growth and sunshine hours during the reproductive and ripening stages of crop growth. A negative correlation was observed for maximum temperature, minimum temperature and growing degree days (GDD) or cumulative heat units. Eventhough, there was no marked difference between date of planting in maximum and minimum temperature, the growing degree days or cumulative heat units received by early planted crop was more resulting in lower plant heights. Late planted crop received more number of bright sunshine hours which might have resulted in taller plant. This was in agreement with the findings of Sankar and Gupta (1981). Photoperiod in addition to its effect on flowering, may influence elongation and branching of stem. This was reported by Venkataraman and Krishnan (1992). Increased N uptake by the late planted crop may also result in the taller growth of the plant.

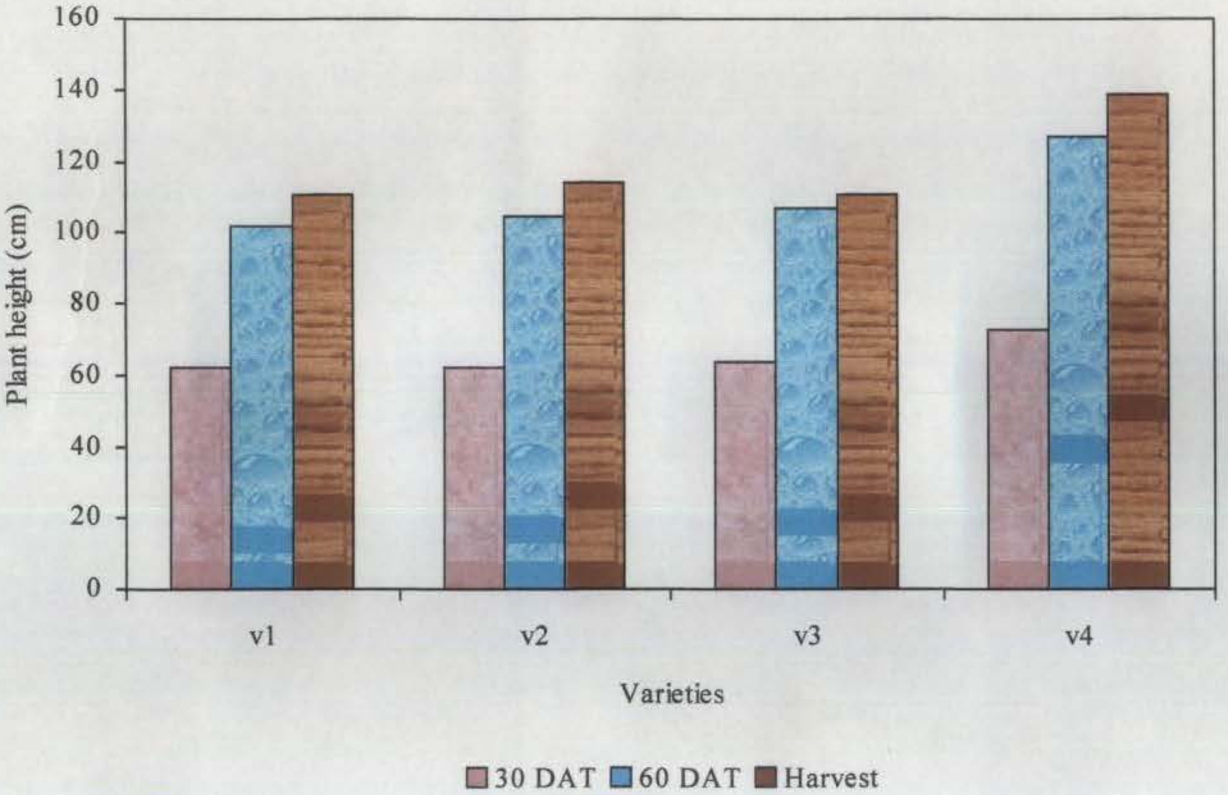


Fig. 6. Influence of variety and date of planting on plant height

The results presented in Table 4.2a (Fig. 7) revealed that number of tillers hill^{-1} was highest for early planted crop except at 30 DAT. More number of tillers at early planting was also reported by Jiang and Zhou (1987), Ramaiah *et al.* (1987) and Sreelatha (1989). The number of tillers at harvest was slightly lower than that at 90 DAT probably due to mutual shading from increased leaf area after maximum tillering stage. This is in agreement with the findings of Krishnakumar (1986). Shading reduces incidence of light and also affects growth and development of the rice plant (Lenka, 1998). Among the varieties, Kasturi recorded maximum number of tillers at all the growth stages. Tiller number showed a positive correlation with minimum temperature during all stages of crop growth and rainfall and relative humidity during vegetative and reproductive stages. Early planted crop experienced sufficient rains combined with relative humidity which increased the number of tillers at various stages of crop growth. Late planted crop experienced a high maximum temperature and low minimum temperature which decreased the number of tillers. This is probably due to the fact that higher temperature will decrease the carbohydrate per plant leading to low tiller production. This was reported by Sato (1972) and Krishnakumar (1986).

Varieties and dates of planting significantly influenced the leaf area index at all stages during crop growth (Table 4.3a and Fig. 8). Among the varieties Haryana basmati recorded maximum leaf area index at 60 DAT and at harvest. Leaf area index showed a slight increase in trend with delay in transplanting. Leaf area index was positively correlated with maximum temperature at vegetative and reproductive stages of crop growth. The late planted crop experienced a relatively higher maximum temperature resulting in an increase in leaf area index. Since there was a negative correlation between leaf area index and rainfall and relative humidity during early stages of crop growth, the early planted crop produced a lower leaf area index. As the height of the plant increased under late planted condition, it might have contributed to more number of leaves and thereby an increase in leaf area index. Eventhough leaf area index

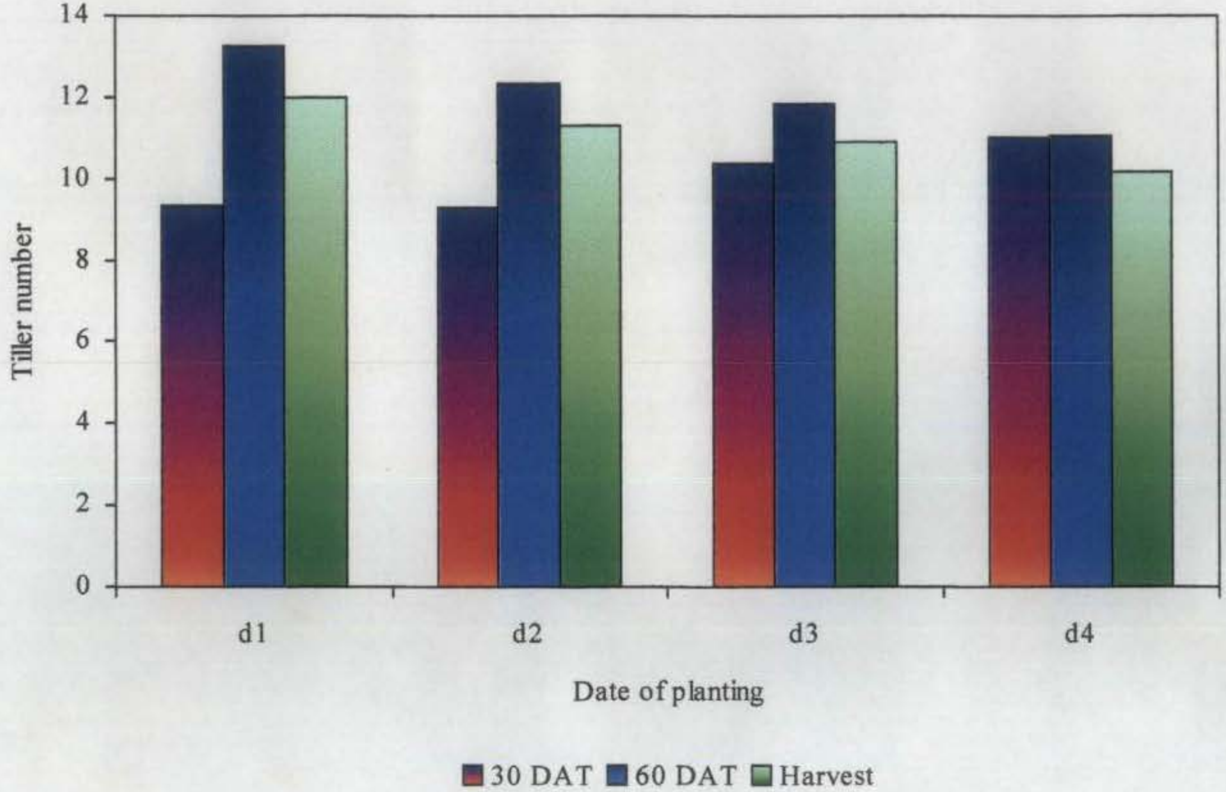


Fig. 7. Influence of date of planting on tiller number

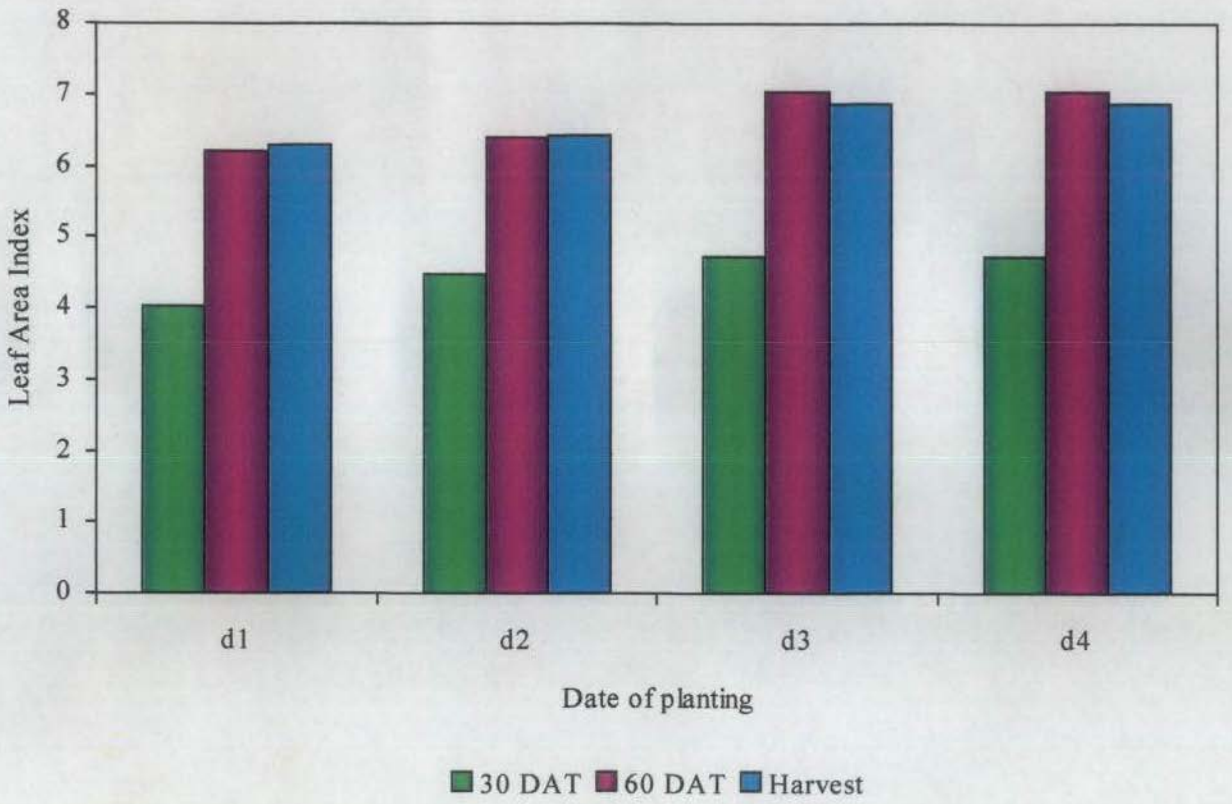
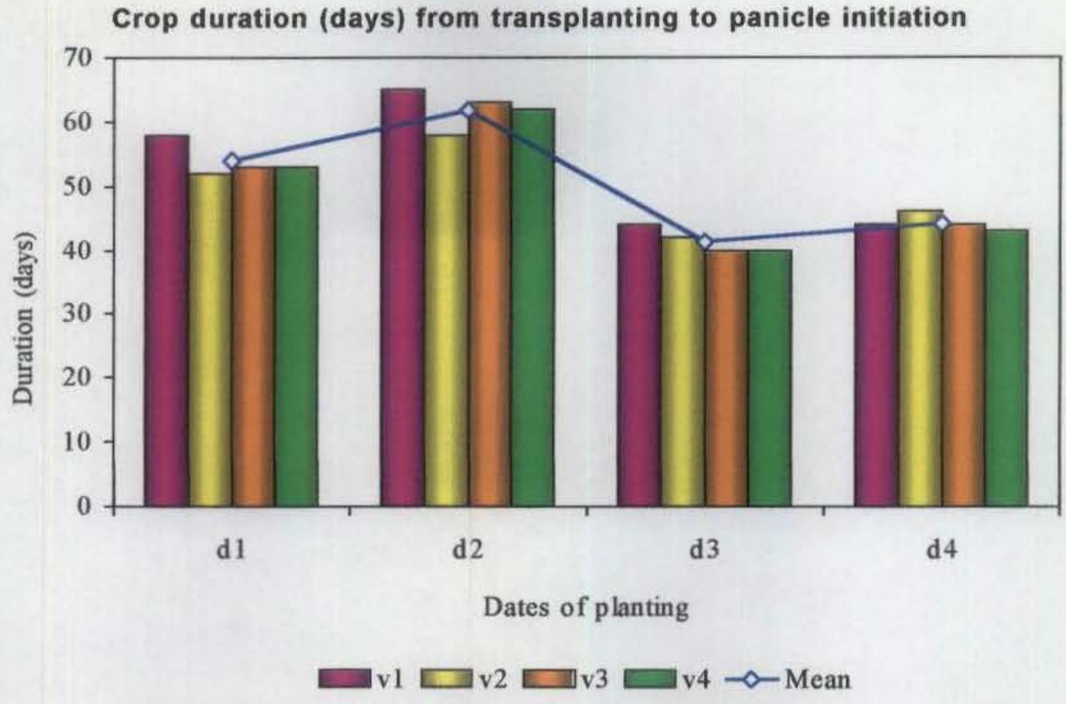


Fig. 8. Influence of date of planting on Leaf Area Index

was slightly more under late planted condition, the high temperature experienced by the crop during these stages resulted in the production of ineffective tillers resulting in low yield. This was also reported by Lin (1976) and Lalitha *et al.* (1999). Interaction effect was significant only at 30 DAT.

Table 4.4 showed that there was a slight decrease in total duration of all the varieties with delay in planting time (Fig. 9). As in any other crop, yields of rice crop are not only reduced by planting dates in a season that will cause plants to flower early but also by planting dates that will cause very late flowering. This was in agreement with the findings of Reddy and Reddy (1986) and Reddy and Reddy (1992). Length of rainy season determines the duration of varieties. Early planted crop received more amount of rainfall which might have increased the duration of the crop. This was reported by Sastri (1986). Low rainfall and relative humidity , high maximum temperature, more number of bright sunshine hours shortened the duration of flowering to harvest for late planted crop. At high temperature translocation of photosynthates to grain takes place at a faster rate and thus maturity get shortened. This was reported by Krishnakumar (1986).

Irrespective of varieties, earlier planting recorded maximum dry matter production (Table 4.5a). This was also reported by Ramaiah *et al.* (1987), Wang and Liu (1991), Singh *et al.* (1993) and Jand *et al.* (1994). Correlation studies revealed that dry matter production was positively influenced by minimum temperature at early growth stage. Kembuchetty (1978) reported that dry matter production decreased when night temperature during vegetative phase was lesser. Relative humidity and rainfall during the entire crop period had positive correlation with dry matter production. Bright sunshine hours also had a positive correlation during the later stages of crop growth. Early planted crop received sufficient rains and relative humidity during the whole crop period which increased the tiller production leading to more dry matter production. Maximum temperature had a negative correlation with dry matter production resulting in low dry matter production in late planted crop. The cumulative heat units was also



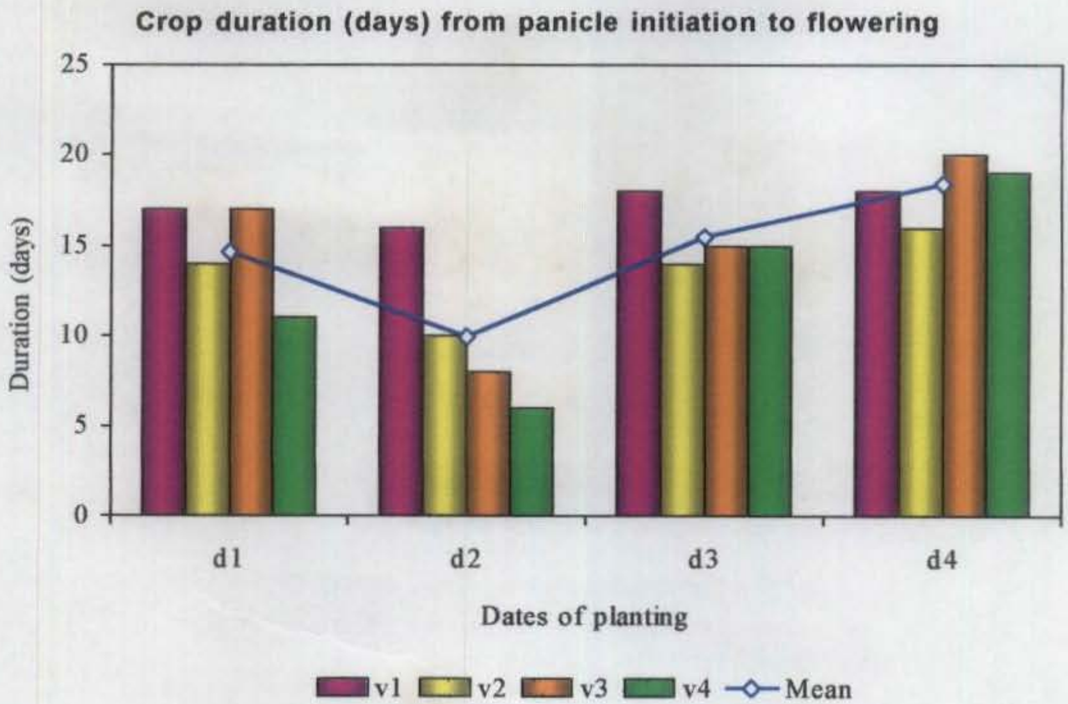
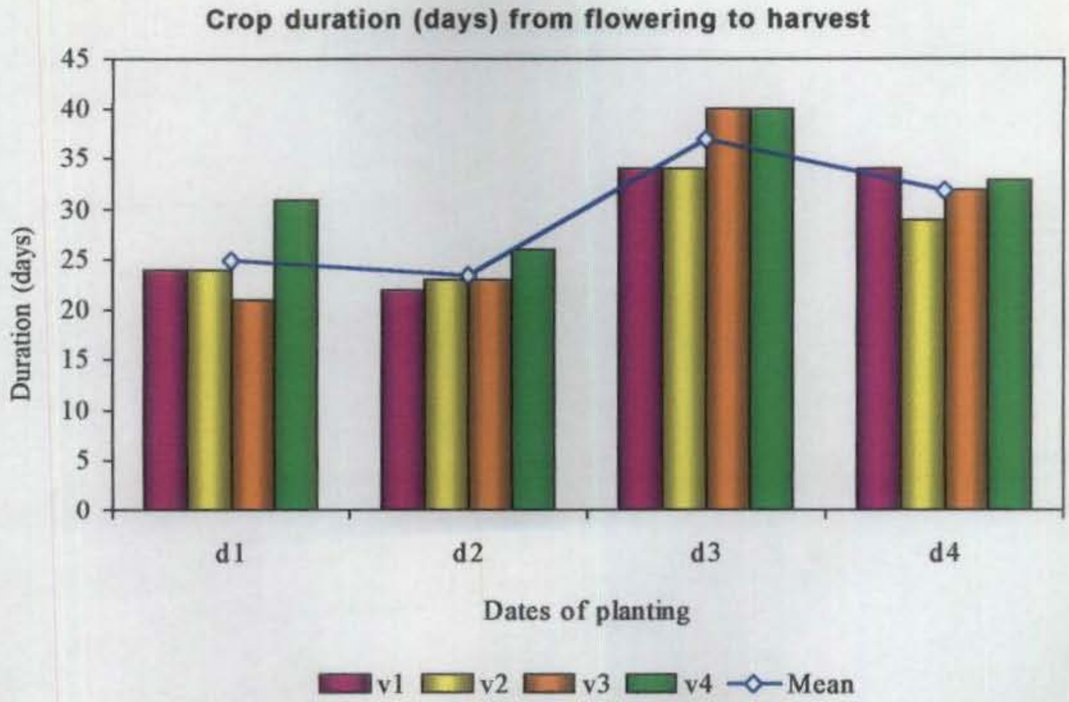


Fig. 9. Influence of planting dates on crop duration



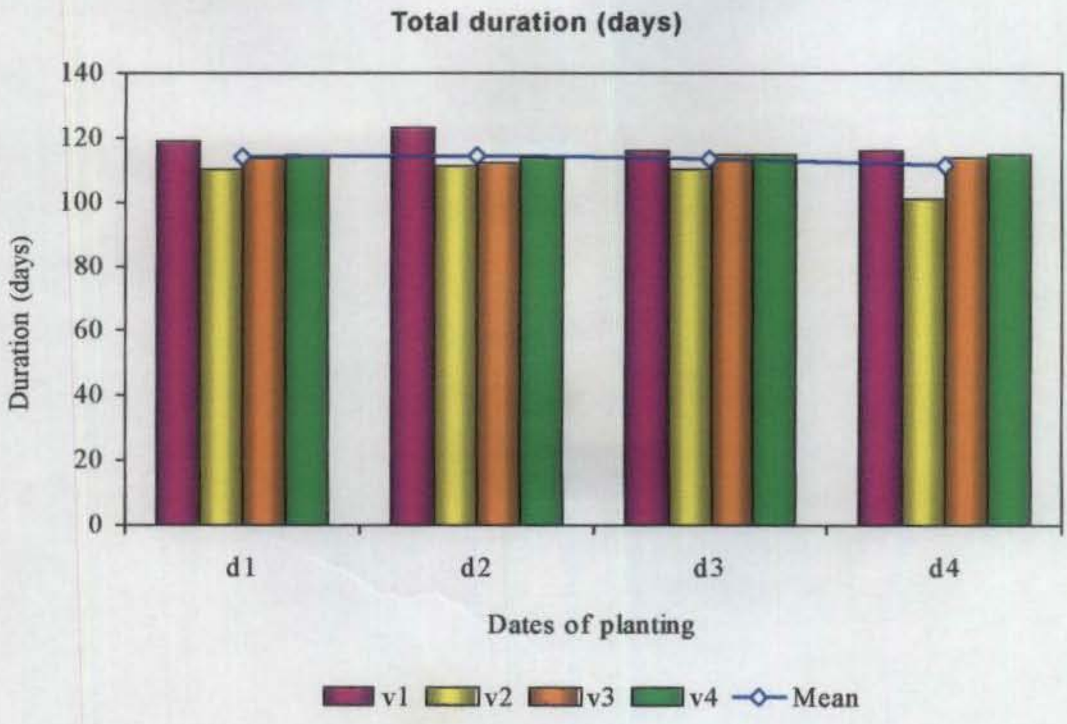


Fig. 9. (Continued)

negatively correlated with dry matter production in its early stages. The late planted crop received more cumulative heat units in vegetative and reproductive phases resulting in lower dry matter production in late planted crop.

5.2 YIELD AND YIELD ATTRIBUTING CHARACTERS

The results presented in Table 4.5a (Fig. 10) revealed that date of planting significantly influenced the number of productive tillers. Early planting recorded maximum number of productive tillers. This was also reported by Ashraf *et al.* (1989) and Ramesh and Singh (1999). Early planting received sufficient rains and other congenial range of weather parameters right from active tillering to panicle initiation stage which contributed to more number of productive tillers. Late planted crop experienced a higher temperature which led to increased production of ineffective tillers. This was reported by Lin (1976) and Krishnakumar (1986).

Eventhough the varieties showed no significant variation in panicle length, date of planting had significant influence on panicle length (Table 4.5a). Early planted crop recorded longest panicle. This was also reported by Kamalam and Havanagi (1987), Singh *et al.* (1991) and Perumal (1989). Among the varieties Kasturi recorded longest panicle.

The results presented in Table 4.5a showed that early planted crop recorded more number of filled grains per panicle. This was also reported by Singh *et al.* (1991). Rainfall and relative humidity had positive correlation with number of filled grains per panicle. The early planted crop received more rainfall and relative humidity compared to late planted crop and this might be the cause of more number of filled grains per panicle in early planted crop. Though maximum and minimum temperatures had negative correlation with filled grains per pancile, the cumulative degree days had positive correlation at all stages except whole crop growth period. Late planted crop appeared to have high amount of chalky kernals. Higher maximum and lower minimum temperature during the whole

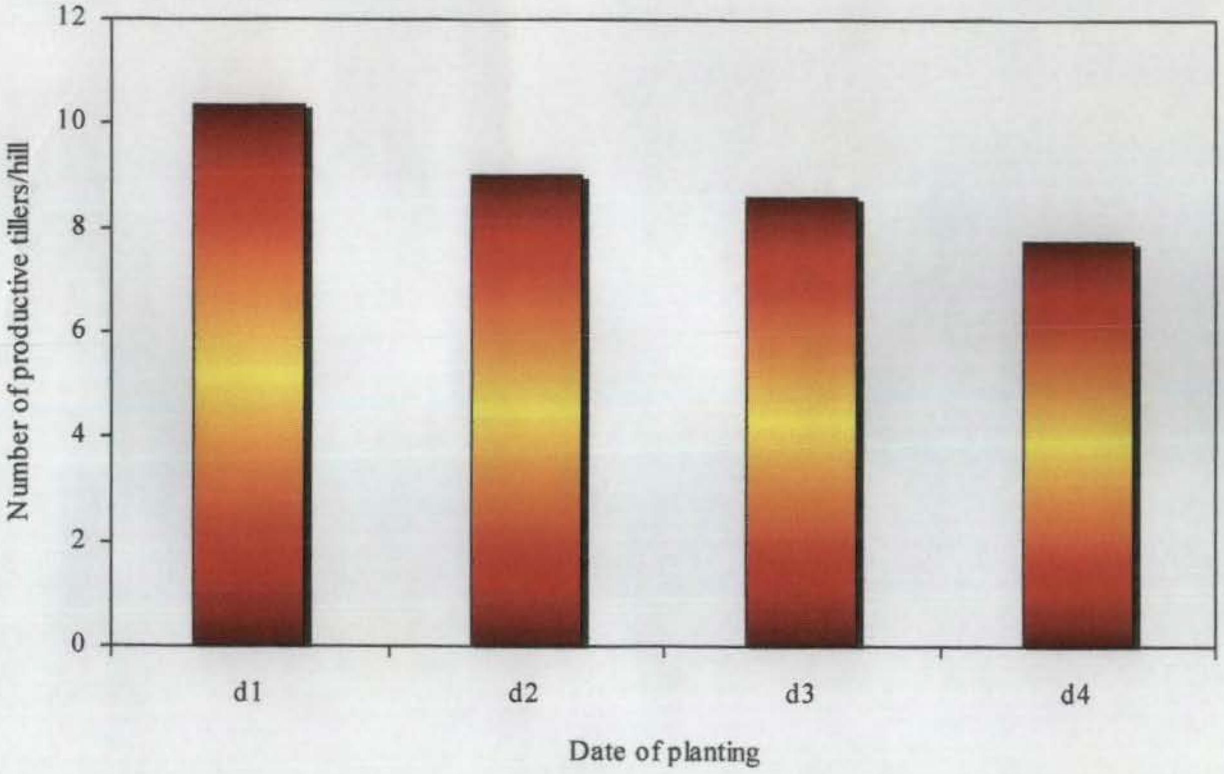


Fig. 10. Influence of date of planting on number of productive tillers/hill

crop period might be the reason for the lesser number of filled grains in later planting. Another reason for the significant lower number of filled grains in later plantings is that source was a limiting factor compared to higher sink. Also wind had a negative correlation with number of filled grains per panicle. Comparatively higher wind and temperature during the period from heading to ripening phase of late planted crop increased the spikelet sterility through higher evaporation rate and desiccation of spikelets. This decreased the percentage of filled grains. This was reported by Krishnakumar (1986) and Matsui (1997).

Higher nutrient uptake and dry matter production lead to more thousand grain weight in early planted crop (Table 4.5a). This was reported by Singh *et al.* (1991) and Singh *et al.* (1993). Among the varieties Kasturi recorded maximum thousand grain weight. High temperature reduces the grain weight accompanied by decrease in grain thickness. Maximum temperature had a negative correlation with 1000 grain weight during all stages of crop growth. Late planted crop experienced fairly higher maximum temperature during the ripening period which shortened the grain filling and maturity stages leading to lesser grain weight. According to IRRI (1980) high air temperature accelerate the development of kernels in early stages of ripening period but depresses them at later stages. This hastens the ripening process and reduces the grain weight.

Date of planting had no significant influence on weight of panicle (Table 4.5a). In general early planted crop recorded heavier panicle. This was also reported by Kamalam and Havanagi (1987) and Singh *et al.* (1991). Among the varieties Kasturi recorded maximum panicle weight because of greater number of spikelets panicle^{-1} and thousand grain weight. Maximum temperature had a negative correlation during all the three growth stages while rainfall, relative humidity and BSS hours had a positive relationship with panicle weight. Higher maximum and lower minimum temperature during the later period may result in lesser number of filled grains in later planting. This may be the reason for decreased panicle weight with delay in planting (Sreelatha, 1989).

The results presented in Table 4.6a revealed that early planting recorded maximum number of spikelets panicle^{-1}. This was in agreement with the findings of Kamalam and Havanagi (1987), Ashraf (1989) and Singh *et al.* (1991). Among the varieties Haryana basmati recorded the maximum number of spikelets panicle^{-1}. Haryana basmati have a longer duration of 115 days which is higher than all other varieties. The nitrogen uptake by this variety was also higher. All these factors may result in higher number of spikelets panicle^{-1}.

The results presented in Table 4.7a (Fig. 11 and 12) revealed that early planted crop recorded maximum grain yield which was 40.6 % higher than late planted crop. Everywhere highest rice yields are associated with sowing / planting within a specific period. The limits of source and sink development are so well related that late sowing / planting limits the development of one or both so that the yields decrease (Lenka, 1998). Reduction in yields of 'IR8' from 3.85 t when planted on June 30 to 1.16 t when planted on September 15 was reported by Biswal, 1988. Higher grain yield for early planted crop was also reported by Narayanaswamy *et al.* (1982), Akram *et al.* (1985) and Dhaliwal *et al.* (1986). The decrease in yield in late planted crop was partly due to the result of more number of non productive tillers contributing to more chaff and partly filled grains. This was in agreement with the findings of Padmaja (1990). Correlation studies between weather parameters and grain yield revealed that there was a significant positive correlation between minimum temperature, relative humidity and rainfall during all stages of crop growth whereas cumulative heat units or growing degree days had positive correlation at all stages except reproductive stage. So the early planted crop received more rainfall and cumulative heat units which might have resulted in the higher grain yield. Higher temperature, lower rainfall and relative humidity in the later stages of growth, high winds which increased the sterility and pollen dehydration may be the reasons for very low yields by late planting. Although higher temperatures in the later sowings are conducive to higher rates of growth, the final plant heights and yields worked out to be lower than those obtained in the optimum sowings in wheat (Sing *et al.*,

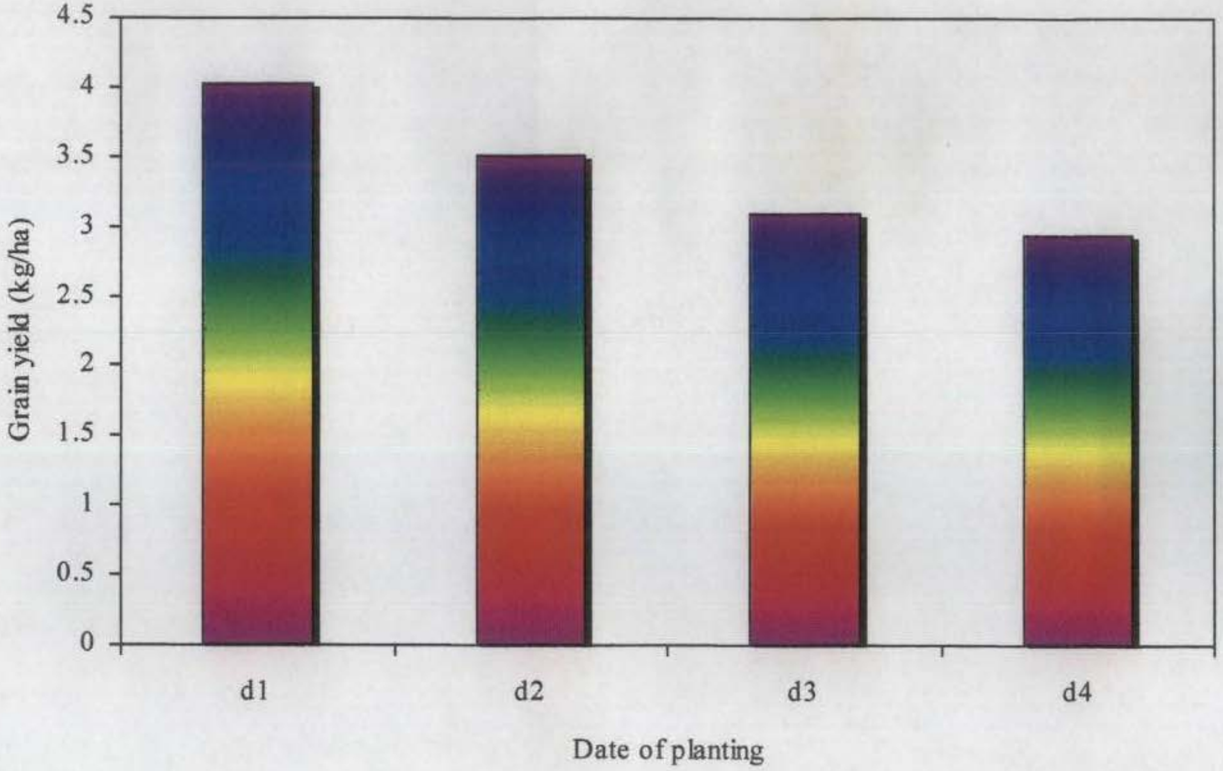


Fig. 11. Influence of date of planting on grain yield

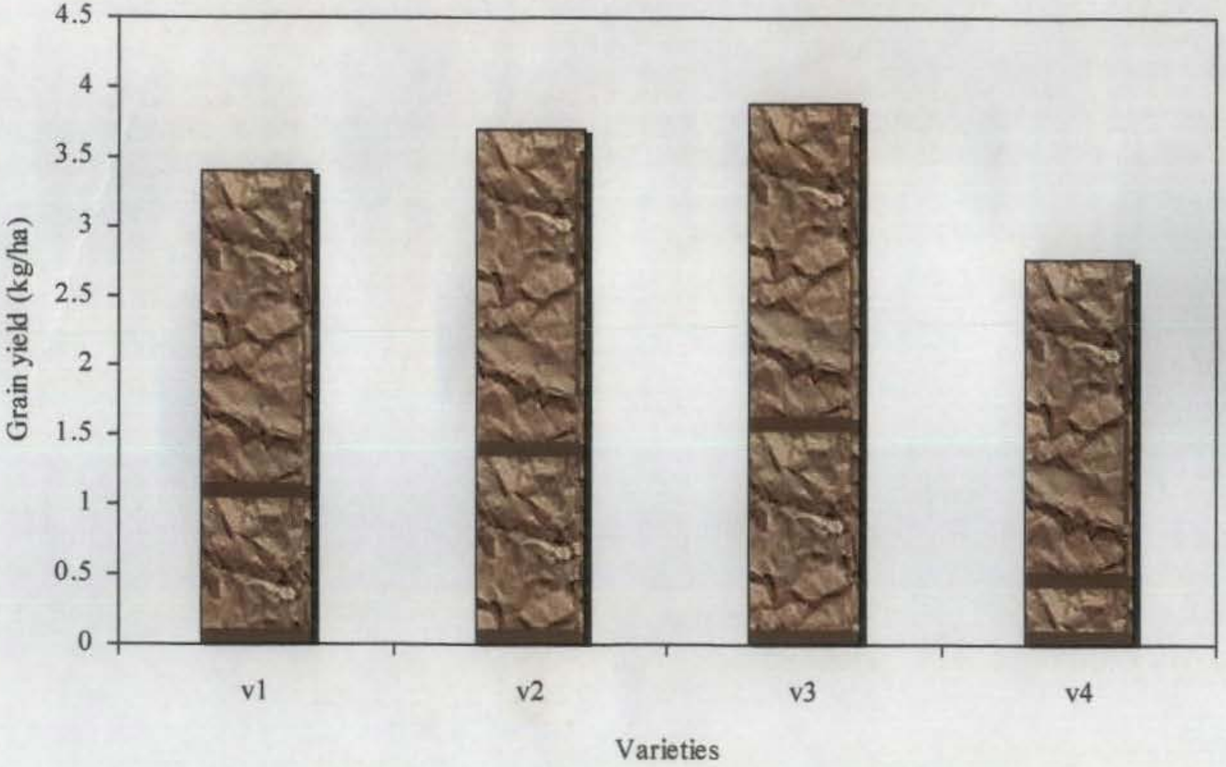


Fig. 12. Influence of varieties on grain yield

1957). High temperature operates negatively on several major aspects of yield determination especially through reduced duration of the spike growth and grain growth period and through other vegetative effects on source and sink in wheat. The extent of reduction in grain yield due to delay in sowing also varies with the genotypes (Behera and Jena, 1998). Both low temperature and high temperature during panicle development induce sterility, though it remains a varietal character to some extent. Among the varieties Kasturi recorded highest grain yield because it has longest and heavier panicle, more number of filled grains and thousand grain weight. This was in agreement with the finding of Amarjit *et al.* (1993).

Delayed planting resulted in a slight decrease in straw yield (Table 4.7a). The decreased straw yield with delayed planting was also reported by Reddy and Narayana (1981) and Amarjit *et al.* (1993). The straw yield of 'IR8' decreased from 4.66 t ha^{-1} to 1.81 t ha^{-1} when planting was delayed from June 30 to September 15 (Biswal, 1988). Early planted crop received more rainfall and thus higher relative humidity during the vegetative period. Also it experienced moderate minimum temperature during the grain filling stage. This lead to more production of straw by the early planted crop. This was also reported by Sreelatha (1989). Late planted crop experienced a fairly high temperature during the growth period and also experienced higher wind at the reproductive stage. Late planted crop though enjoying more bright sunshine hours, matured with less temperature units. Hence, BSH per se may not be the limiting factor. It is the initial growth triggered by temperature regime that plays a more important role than other factors (Lenka, 1998). The reduced dry matter production also lead to slight decrease in straw yield. Eventhough there was no significant difference among the varieties with respect to straw yield, Pusa basmati-1 recorded maximum straw yield.

Harvest index was significantly influenced by varieties and date of planting (Table 4.7a). Minimum temperature, relative humidity and BSS hours were positively correlated with harvest index. There was also positive correlation noticed between rainfall and harvest index at all stages except maturity stage. Eventhough BSS hours was positively correlated with harvest index, the late planted crop which received more sunshine hours recorded low harvest index value. This can be attributed to the negative correlation of BSS hours with grain yield and positive correlation with dry matter production during reproductive and maturity stages of crop growth. Early planted crops gave higher harvest index due to the high rainfall, minimum temperature and relative humidity throughout the crop growth period. Similar results were obtained by Narayanaswamy *et al.*, 1982. Higher harvest index in early planting indicates that a higher portion of photosynthates translocated to sink. Maximum temperature and growing degree days (GDD) were negatively correlated with harvest index. Late planted crop experienced a high temperature which lead to a decrease in harvest index (IRRI, 1980).

5.3 COOKING QUALITIES

Table 4.8a showed that planting time had no significant influence on cooking time of the varieties. Among the varieties, Basmati-370 took less time for cooking compared to other varieties. Eventhough Basmati-370 took less time for cooking other quality aspects like elongation, volume expansion, taste, aroma etc. were inferior to rest of the varieties.

Lengthwise expansion without increase in girth is considered to be a highly desirable trait in high quality rices. Table 4.8a showed that varieties differ significant in elongation ratio. Pusa basmati-1 recorded the maximum elongation ratio of 1.67 which indicate that it is a superior variety. Planting time had shown no significant influence on elongation. Grain elongation was influenced by temperature at the time of ripening. According to Cruz (1991) maximum grain elongation was at 25/21°C day/night temperature.

Among the varieties Pusa basmati-1 recorded maximum volume expansion (Table 4.8a) which is a superior quality as far as aromatic rices are considered. This was reported by Singh (2000). Planting time had no significant influence on volume expansion.

The attributes of appearance, tenderness and flavour of cooked rice are the final criteria of cooking quality and determine the palatability or eating characteristics of cooked rice. Table 4.9 revealed that among the varieties Kasturi performed well with respect to quality characters. Haryana basmati was least accepted because of poor quality attributes. Indian consumers value aroma most followed by elongation after cooking (Singh and Singh (1997). Kasturi obtained the highest rank for overall acceptability whereas Pusa basmati-1 and Basmati-370 comes in the second position.

Basmati rice require relatively cooler temperature (25°C/21°C day/night temperature) during crop maturity for better retention of aroma. Maximum grain elongation was also observed at this temperature during ripening. Early planting coinciding with the flowering and maturity in cooler days has reported to enhance the grain quality of aromatic rices tested by singh *et al.* (1993) Chandra *et al.* (1997) and Thakur *et al.* (1996).

5.4 NUTRIENT UPTAKE

The results (Tables 4.10a and 4.10b) revealed that uptake of N and K were significantly influenced by varieties and date of planting. Among the varieties Haryana basmati recorded maximum N and K uptake. Larger dry matter production is a contributing factor to increased uptake of nutrients (Perumal, 1989). Early planted crop showed a slight decrease in the uptake of N because early planted crop received good amount of rainfall which lead to leaching loss of some nitrogen. This was also reported by Perumal (1989). Potassium application increased the yield in scented rice through increased grain weight, reduced sterility and decreased lodging. This was reported by Mehta *et al.* (1995). Nitrogen application significantly increased the plant height in Basmati-370. This was reported by Zhilin *et al.* (1997). Eventhough P uptake was not significantly influenced by varieties and planting time Kasturi recorded maximum uptake when planted on 23rd October.

5.5 INCIDENCE OF PESTS AND DISEASES

Table 4.11a revealed that among the varieties Pusa basmati-1 was more susceptible to sheath blight disease in all the four transplanting dates. But maximum infestation was recorded in the later part of the early planted crop. This may be due to higher relative humidity and a fairly high temperature during later parts. Maximum temperature, rainfall and relative humidity had a positive correlation with sheath blight disease while minimum temperature and BSS hours had a negative relationship. Since Pusa basmati-1 is a high yielding variety with short stature and profuse tillering and highly responsive to nitrogen and phosphorus, this variety is particularly susceptible to sheath blight disease. This was reported by Singh *et al.* (2000).

5.6 COST OF CULTIVATION

Table 4.12a (Fig. 13) revealed that variety and date of planting had significant influence on net returns and benefit cost ratio. Maximum returns was obtained for Kasturi planted on 10th October. As this variety possess more number of productive tillers, filled grains panicle^{-1}, thousand grain weight and grain yield, the net returns were also higher for this variety. Earlier planting received fairly good amount of rainfall during the vegetative growth period, low temperature during flowering and ripening stages, more number of bright sunshine hours during the reproductive stages, grain yield was higher which contributed to high net returns.

Benefit cost ratio (BC ratio) was also higher for Kasturi planted on 10th October. The yield and yield attributing characters were more in earlier planting and for the variety Kasturi which might have resulted in a higher BC ratio. Similarly as the planting time was advanced, yield of grain as well as straw were decreased which lead to a lower BC ratio.

5.7 AGROMETEOROLOGICAL STUDIES

Growing degree days / Cumulative heat units

The resuls presented in Table 4.14a revealed that there was difference between varieties and different dates of planting in the cumulative heat units required for the completion of different phenological phases. The variety Kasturi needed less cumulative heat units to complete the vegetative phase when compared to the other varieties. The variety Haryana basmati needed more cumulative heat units to complete the first phase while it was compensated in the reproductive and maturity phases of crop growth. However, Kasturi took less cumulative heat units to reach maturity and Pusa basmati the most. The variety Kasturi recorded the highest grain yield, possess first ranking in quality attributes and matures within short period. Because of all these factors the variety Kasturi can be recommended from among the varieties for cultivation in the Southern agroclimatic region of Kerala.

The cumulative heat units requirement of d_2 (23rd October planting) was less when compared to other dates and among the combination Basmati-370 planted on 23rd October took the least cumulative heat units to mature. Hence it can be recommended that the ideal time of planting of basmati rice crop is 23rd

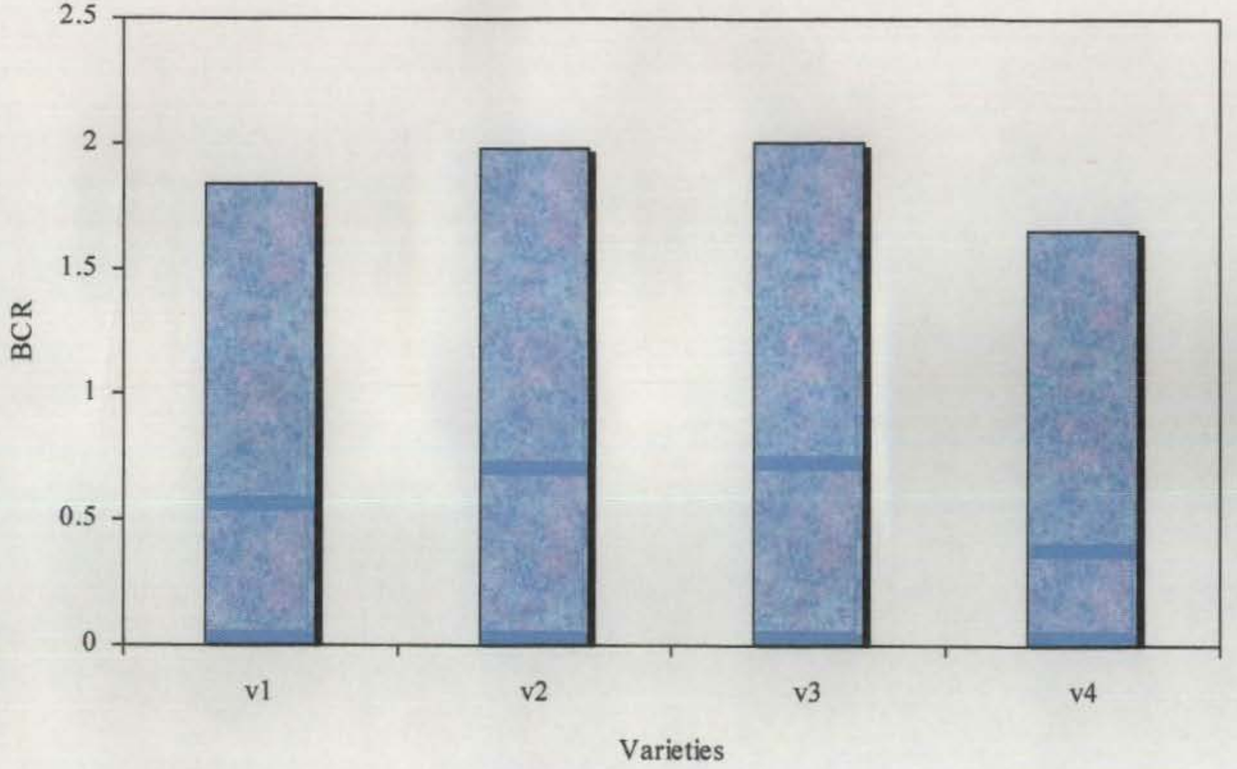


Fig. 13. Influence of varieties on BCR

October for early maturity. Since the cumulative heat units and yield were positively correlated, for getting higher yield 10th October planting was found to be ideal, eventhough the cumulative heat unit requirement was slightly more.

The phenological stages of crop can be predicted based on growing degree days concept and accordingly the microclimate can be modified or changed in such a way as to produce the nearly optimum conditions at each point in the developmental cycle of the crop (Mavi, 1986).

The early planted crops required more photothermal units to mature when compared to delayed planting and the least requirement was for 23rd October planting, indicating that temperature conditions and day length hours during this period is favourable for basmati rice cultivation in Southern part of Kerala (Table 4.16). The variety Basmati-370 which is a traditional variety required less photothermal units for maturity followed by Kasturi which is a high yielder. But in the case of heliothermal units (Table 4.17), Haryana basmati required less heliothermal units to mature indicating that the duration is affected by bright sunshine hours. This was followed by Basmati-370. Planting on 23rd October again required less heliothermal units to mature suggesting that 23rd October is the best planting time when Basmati rice is considered. Among the combination effect, Haryana basmati planted on 23rd October required the least heliothermal units to mature indicating the suitability of 23rd October or 4th week of October as planting time of basmati rice in the southern part of Kerala. The accumulated heliothermal unit is negatively correlated with yield indicating that with a decrease in accumulated heliothermal units, the grain yield was found higher for d_1 (October 10th planting) suggesting the role of sunshine hours in deciding the yield of a crop. There was a negative correlation between sunshine hours and yield during reproductive and maturity stages resulting in higher yield in early planted crop. Table 4.17a and 4.18b showed that the variety Basmati-370 which is a traditional variety recorded the highest heat unit efficiency indicating that this variety is the best utilizer of radiation parameters. The variety Haryana basmati came next to Basmati-370 in heat unit efficiency. Regarding date of planting 23rd October planting produced the highest heat unit efficiency followed by 10th October planting. Basmati varieties planted on 23rd October gave the highest heat unit efficiency indicating that the radiation parameters were well utilised by the crop when it was planted on 23rd October. Though the DMP of d_1 (10th October planting) was higher its heat unit efficiency was less indicating the less efficient utilisation of radiation parameters ie., for unit production of dry matter more cumulative heat units were utilised. This may be due to the heavy rainfall during that period. The variety Basmati-370 planted on 23rd October recorded the highest heat unit efficiency of 0.74 followed by October 10th planting of the same variety.

Relationship between meteorological parameters and growth characters

Table 4.19a revealed that plant height had a negative correlation with maximum temperature, sunshine hours, wind and cumulative heat units. A significant negative correlation between height of the crop and maximum temperature was reported by Shankar and Gupta (1981). A positive correlation was obtained with minimum temperature, rainfall, relative humidity and accumulated heliothermal units. Tiller number showed a positive correlation with minimum temperature, rainfall, relative humidity and accumulated heliothermal units while a negative correlation was obtained with maximum temperature, sunshine hours, wind and cumulative heat units. Increased production of ineffective tillers with high temperature was also reported by Lin (1976). During the reproductive stage minimum temperature, rainfall and relative humidity showed a positive correlation with tiller number while a negative correlation was obtained with maximum temperature, sunshine hours, wind, accumulated heliothermal units and cumulative heat units. Leaf area index showed a positive correlation with maximum temperature and accumulated heliothermal units while a negative correlation was obtained with minimum temperature, rainfall and relative humidity during the vegetative stage. During the reproductive stage, a positive correlation was obtained with maximum temperature, sunshine hours and wind while a negative correlation was obtained with minimum temperature, rainfall, sunshine hours and cumulative degree days. Krishnakumar (1986) also reported a negative correlation with sunshine hours during the later phases of crop growth.

Dry matter production showed a negative correlation with maximum temperature and wind during all the growth stages while a positive correlation was obtained with rainfall and relative humidity. A positive correlation was obtained with minimum temperature during the vegetative phase. This was also reported by Kembuchetty (1968). Sufficient rains received by the crop resulted in increased dry matter production in early planted crop.

Relationship between meteorological parameters and duration of different phenophases of basmati rice varieties

The results presented in the Table 4.19b showed that maximum temperature had a negative correlation with duration from transplanting to maximum tillering stage (P_1) and 100% flowering to maturity stage (P_5) of the crop. Early planting took more days for completing the first phase while late planting took less number of days for completing this phase. The mean maximum temperature of the late planted crop is comparatively higher and this can be attributed to the lesser number of days. Shortened duration of rice plant with high temperature was also reported by Owen (1971). Maximum temperature is negatively correlated with duration during crop maturity period. Rajagopalan *et al.* (1973) observed a highly significant negative correlation between temperature and growth duration. Eventhough, maximum temperature had a positive correlation with duration during P_2, P_3 and P_4 phases of crop growth, the late planted crop which experienced a high maximum temperature took less number of days. This can be attributed to the negative correlation of duration and sunshine hours. The late planted crop received more sunshine hours upto maturity stage resulting in a decrease in number of days taken for the second, third and fourth phases of crop growth. Minimum temperature is positively correlated with duration during the first and last two phases of crop growth while negatively correlated in P_2 and P_3 phases of crop growth. This was also reported by Vergara *et al.* (1970) and Krishnakumar (1986). Rainfall is negatively correlated with duration during P_2 and P_3 phases of crop growth. Reddy and Reddy (1992) reported that number of days required to 50 per cent flowering and crop duration were decreased by delayed planting. Reddy and Reddy (1986) also reported same results. Sunshine hours is negatively correlated in the middle three phases so that the total duration is decreased with a high amount of bright sunshine hours. Late planted crop took less number of days for maturity because of the high amount of bright sunshine hours received.

Relationship between meteorological parameters and yield and yield attributes

The results presented in the Table 4.19c showed that panicle weight had a positive correlation with rainfall, relative humidity and sunshine hours during all the growth stages. This was also reported by Sreedharan (1975). Panicle weight showed a negative correlation with maximum temperature, minimum temperature, wind, cumulative heat units and accumulated heliothermal units. Number of spikelets panicle^{-1} showed a positive correlation with relative humidity, rainfall, minimum temperature and cumulative heat units during the vegetative, reproductive and maturity stages. There was a high positive correlation of grain number m^{-2} with solar radiation during 25 days before flowering (IRRI, 1974). Sahu *et al.* (1983) reported a positive correlation between yield attributes and solar energy during reproductive and maturity stages. Thousand grain weight showed a positive correlation with rainfall, relative humidity, sunshine hours and cumulative heat units during maturity and whole growth period of crop. This was also reported by Krishnakumar (1986). Thousand grain weight had a negative correlation with maximum temperature. The correlation between the agronomic factors and microclimate indicated that the later sowings are associated with shorter ripening period and lower values of thousand grain weight mainly due to the higher temperatures between the ear emergence and the harvesting period in wheat (Singh *et al.*, 1957). Yield had a positive correlation with rainfall and relative humidity during all the growth stages while a negative correlation was obtained with maximum temperature, wind and heliothermal units. Radhakrishnamurthy *et al.* (2000) also obtained a negative correlation between yield and heliothermal units in soyabean. He also reported a negative influence of high air temperature on vegetative growth period of soyabean on seed yield. A negative correlation between wind and yield of rice was reported by Viswambharan *et al.* (1989). Rice yields were significantly correlated with quantum of rainfall, length of rainy season and number of rainy days (Venkatesarlu, 1976). Harvest index showed a positive correlation with relative humidity, sunshine hours, minimum temperature while a negative correlation was obtained with maximum temperature, rainfall, wind, cumulative heat units and accumulated heliothermal units during the maturity stage. As the maximum temperature increases, rice yield decreases leading to decreased harvest index of the crop.

Future line of work

The productivity and quality of the aromatic rices depend on the environmental conditions of the area where they are grown and the crop management practices followed to grow the crop. Although aromatic rices are cultivated for long time, research attention was mainly on the varietal development and productivity aspects. Information on the influence of management aspects and environmental conditions on the quality of rice are meagre. So there is a need to scientifically verify and define those factors in future line.

SUMMARY

6. SUMMARY

A field experiment was conducted at the Instructional Farm of the College of Agriculture, Vellayani during the second crop season of 2001 to study the performance of basmati rice varieties under different dates of planting. The experiment was laid out in strip plot design with three replications. The treatments consisted of combinations of four varieties (v_1 - Pusa basmati-1, v_2 - Haryana basmati, v_3 - Kasturi and v_4 - Basmati-370) and four dates of planting (d_1 - October 10, d_2 - October 23, d_3 - November 5 and d_4 - November 18). Observations on biometric and yield attributing characters and yield, nutrient uptake, quality aspects, agrometerological parameters and economics of the treatments were collected, statistically analysed and the results of the study are summarised below.

Plant height was significantly influenced by varieties at all growth stages and the variety Pusa basmati-1 recorded the lowest height throughout the growth stages. There was a progressive increase in plant height with delayed planting at 30 and 60 DAT. Interactions were significant only at 30 DAT. Basmati-370, a traditional variety recorded the maximum height when transplanted on 18^{th} November.

The tiller count was maximum in Haryana basmati during 30 DAT while at harvest Basmati-370 recorded maximum tiller number. Eventhough late planting (18^{th} November) produced slightly more number of tillers at 30 DAT, at harvest there was not much difference between date of planting on tiller count. There was no significant influence of interaction on tiller count.

Eventhough Basmati-370 recorded maximum LAI at 30 DAT, Haryana basmati recorded maximum LAI at 60 DAT and at harvest. Late planting produced slightly higher LAI than early planting.

The duration for panicle initiation was reduced in all varieties in delayed planting. Early planted (10th October) Haryana basmati took more days for panicle initiation whereas late planted (18th November) Kasturi took least number of days for panicle initiation.

Both Kasturi and Basmati-370 planted on 10th October required more days for completing the phase from panicle initiation to flowering whereas Haryana basmati took least number of days. Delayed planting lowered the duration from panicle initiation to flowering.

The duration from flowering to harvest was more for Kasturi and Basmati-370 when compared to other two varieties. Haryana basmati took least number of days for maturity.

The total DMP was significantly influenced by varieties and date of planting. Basmati-370 planted on 10th October recorded maximum DMP. Delayed planting lowered the DMP.

The maximum number of productive tillers hill^{-1} was recorded by Haryana basmati. Productive tillers hill^{-1} were more for early planted crop. Interaction effects were not significant in number of productive tillers.

The varieties failed to have any significant influence on panicle length whereas planting time had significant influence. Early planting (10th October) produced longest panicle.

Panicle weight was significantly influenced by the varieties. Kasturi recorded maximum panicle weight. Planting time and interaction effects had no significant influence on panicle weight.

The number of spikelets panicle^{-1} was maximum in Haryana basmati and was significantly superior to other varieties. Among the interactions highest number of spikelets panicle^{-1} was recorded by Haryana basmati planted on 10th October.

The number of filled grains panicle^{-1} was also higher for Haryana basmati and for earlier planting. Interaction effects failed to produce any significant influence on number of filled grains panicle^{-1}.

Among the varieties, Kasturi recorded maximum thousand grain weight and was significantly superior to all other varieties. Late planting on 18th November slightly reduced the thousand grain weight. Among the interactions, Kasturi planted on 10th October recorded maximum thousand grain weight.

Grain yield was significantly influenced by varieties and date of planting. The variety Kasturi recorded highest grain yield. Delayed planting lowered the grain yield significantly.

Varieties and date of planting failed to produce any significant influence on straw yield. Highest straw yield was recorded by Pusa basmati-1.

Harvest index showed a slight decrease in trend with delayed planting. Kasturi recorded the maximum harvest index.

Cooking time was significantly influenced by the varieties. Basmati-370 took least time for cooking while Haryana basmati took maximum time. Cooking time was not found affected by planting date. Interaction effects had no significant influence on cooking time.

Maximum elongation ratio was recorded by Pusa basmati-1 which was significantly superior to Basmati-370 and Haryana basmati. Planting time and interaction effects failed to produce any significant influence on elongation ratio.

Pusa basmati-1 recorded maximum volume expansion and was significantly superior to all other varieties. Different planting time and interaction effects failed to produce any significant influence on volume expansion.

Sensory evaluation scores for organoleptic qualities showed that highest rank was obtained for Kasturi for all quality attributes. Overall acceptability was also highest for Kasturi followed by Pusa basmati-1

Maximum N uptake was recorded by Haryana basmati which was significantly superior to other varieties. Transplanting on 18th November recorded maximum N uptake.

Varieties and date of planting failed to produce any significant influence on P uptake. Kasturi planted on 23rd October recorded maximum P uptake.

Uptake of K was more for Haryana basmati planted on 10th October.

Scoring on sheath blight disease revealed that Pusa basmati-1 was highly susceptible to sheath blight incidence. Disease incidence was maximum in early planted crop.

Economic analysis of the treatments revealed that maximum net returns and BCR was for the variety Kasturi planted on 10th October.

Agrometerological studies showed that the early planted crop required more GDD, HTU and PTU for maturity. Among the varieties Pusa basmati-1 required more PTU and HTU. But Basmati-370 planted on 23rd October proved to be the efficient variety in utilising heat units for total dry matter production. That means the variety Basmati-370 had the highest HUE.

Correlation studies between weather parameters and growth characters revealed that during vegetative phase, minimum temperature, rainfall, relative humidity and AHTU had a positive influence on plant height, tiller number and DMP while maximum temperature, sunshine hours and GDD had a negative influence. During the reproductive stage, a positive correlation was obtained with rainfall, relative humidity and bright sunshine hours while a negative correlation with maximum temperature, GDD and AHTU. During ripening stage, a negative correlation was obtained with maximum and minimum temperatures and wind.

Correlation analysis between weather parameters and growth duration indicated that during transplanting to maximum tillering stage a positive correlation existed with minimum temperature, rainfall, relative humidity, bright sunshine hours and wind. From maximum tillering to panicle initiation stage a positive correlation was obtained with maximum temperature and wind while from panicle initiation to 50 per cent flowering, a positive correlation was obtained with maximum temperature and GDD. During the period from 50 per cent flowering to 100 per cent flowering maximum and minimum temperature, rainfall and relative humidity showed a positive correlation while during maturity phase a positive correlation was obtained with minimum temperature, rainfall, relative humidity, sunshine hours and GDD.

Correlation analysis between weather parameters and yield and yield attributes revealed that a positive correlation existed between rainfall, relative humidity and GDD during reproductive period. During ripening phase also a positive correlation was obtained with minimum temperature, rainfall, relative humidity and GDD.

Correlation studies between weather parameters and sheath blight intensity revealed that there was a positive correlation between disease incidence and maximum temperature, relative humidity and rainfall.

7. REFERENCES

Akram, M., Cheema, A.S., Awan, M.S. and Ahmad, M. 1985. Effect of planting date and fertilizer level on grain yield and protein content of rice. *Pakist. J. agric. Res.* 6: 165-167

Akram, M., Cheema, A.S. and Awan, M.S. 1987. Effect of planting date and fertilizer level on grain yield and protein content of rice. *Field crop abstr.* 40: 2619

Ali, A., Karim, M.A., Ali, S.S., Ali, L., Hassan, G. and Mazid, A. 1991. Relationship of transplanting time to grain quality in Basmati-385. *Int. Rice Res. Newsl.* 16(4): 5-11

Ali, A., Karim, M.A., Majid, A., Hassan, G. 1993. Grain quality of rice harvested at different maturities. *Int. Rice Res. Notes* 18(2): 11

Ali, A.M. and Ismail, F.M. 1982. Effect of time of sowing and different age of seedlings on grain yield and contributing characters of two rice cultivars. *Res. Bull. Faculty Agriculture. Ain Shams Uni.* p. 12

Amarjit, S., Bate, A.S. and Uppal, H.S. 1993. Effect of date of transplanting and water management practices on yield of basmati rice (*Oryza sativa*). *Indian J. Agron.* 40: 186-192

Angrish, R. 1991. Effect of foliage pruning on lodging and yield of Basmati-370 rice. *Indian J. Pl. Physiol.* 34 : 271-273

Angrish, R. 1998. Photoperiodic characteristics of basmati rice. *Indian J. Pl. Physiol.* 41: 77-81

Angrish, R. and Dhiman, S.D. 1999. Some photoperiodic aspects of basmati rice, growth and development. *Adv. Pl. Sci. Res.* 5: 72-80

Arumugachamy, S., Vairavan, S., Vivekandam, P. and Palaniswamy, S. 1992. Aromatic and quality rice improvement in Tamil Nadu, India. *Int. Rice Res. Newsl.* 17(2) : 11-12

Ashraf, M., Mahmood, S., Munsib, M. and Yousaf, M. 1989. Relationship of transplanting time and grain yield of Basmati-385. *Int. Rice Res. Newsl.* 14(1): 8

Aswathy, L.P. and Pandey, V.K. 2000. Genetic variation in morphological traits of aromatic rice. *Crop Res.* 19: 361-363

Babu, A.M. 1987. Effect of date of planting and variety on growth and yield of rice. *Oryza* 25: 319-322

Babu, S.D. 1996. Yield maximisation of direct sown rice under puddled condition. M.Sc. thesis, Kerala Agricultural University, Thrissur, p. 123

Bali, A.S. and Uppal, H.S. 1999. Soil nitrate profile and root growth of basmati rice under varying transplanting dates and irrigation regime. *J. Appl. Biol.* 1: 25-28

Bandyopadhay, S. and Roy, N.C. 1992. Fundamentals of parboiling. *Rice Process Technology.* Oxford and IBH publishing Co., New Delhi, p. 326

Beena, C. and Balachandran, P.V. 2001. Seasonal influence on grain yield of rice. *J. Trop. Agric.* 36: 72-74

Behera, A.K. 1998. Response of scented rice (*Oryza sativa* L.) to nitrogen under transplanted condition. *Indian J. Agron.* 43: 64-67

Behera, A.K. and Jena, S.N. 1998. Note on effect of temperature on the performance of wheat varieties at different sowing dates. *Indian Agric.* 42: 63-66

Biswal, D. 1988. The effect of temperature on plant growth development and yield. *Proc. symposium on plant response to climate factors*, Uppsala, UNESCO.p. 88-98

Biswas, S., Kapta, P. and Mitra, D. 1975. Studies on relation between heat unit and flowering in rice (*Oryza sativa* L.) *Indian Agric.* 19: 113-120

Boerma, E.B. 1974. Climatic effects on growth and yield of rice in the Murrubidgee Valley of New South Wales, Australia. *Rice* 23: 385-389

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soil. *Agron. J.* 54 : 464-465

*Chae, J.C., Hew, H. and Lee, J.H. 1980. Effect of air and water temperature on the growth and nutrient uptake of rice cultivars. *J. Korean Crop. Sci. Soc.* 25: 14-19

Chandler, R.F.C. 1963. Analysis of factors affecting rice yield. *Int. Rice Commun. Newsl.* 12(1): 1-17

Chandra, D., Lodh, S.B., Sahoo, M.K. and Nanda, B.B. 1997. Effect of date of planting and spacing on grain yield and quality of scented rice (*Oryza sativa* L.) varieties in wet season in coastal Orissa. *Indian J. agric. Sci.* 67 : 93-97

Chatterjee, B.N. 1970. Tiller production in paddy and its effects on grain yield. *Rice* 19: 245-256

Chatterjee, B.N. and Maithy, S. 1981. Harvesting, processing and storing (In) *Principles and Practices of Rice Growing.* Oxford and IBH publishing Co. Ltd., New Delhi, p. 411

Chaubey, P.K., Nanda, B.B. and Richoriya, A.K. 1988. Quality attributing characters of scented and nonscented rice. *Oryza* 25: 325-328

Chikkalingaiah, E., Gangappa, S., Ramesh and Rao, A.M. 1997. Evaluation of some aromatic rice for quality traits. *Mysore J. agric. Sci.* 31 : 201-233

Choudhary, A. and Gore, P.G. 1991. Effect of weather on rice crop in Bhandra district : a curvilinear approach. *Mausam* 42: 279-286

Choudhary, B.T., Turkhade, A.B., Chore, C.N., Jiotode, D.J. and Thorat, A.W. 1998. Effect of transplanting time on the grain yield of scented rice varieties. *J. Soils Crops* 8 : 147-149

Choudhary, M. 1984. Effect of sowing date on growth and performance of six rice varieties in western Turkey. *Int. Rice Res. Newsl.* 9(2): 24

Choudhary, T.N. and Ghildyal, B.P. 1970. Influence of submerged soil temperature regime on growth, yield and nutrient composition of rice plant. *Agron. J.* 62: 281-285

Choudhary, T.N. and Sodhi, T.S. 1979. Effect of weather factors on growth of rice planted at different dates in a humid tropical area. *Rice* 28: 255-263

Cochran, W.C. and Cox, G.M. 1965. *Experimental Designs.* John Wiley and Sons. Inc., New York p. 261

CRRI, 1994. Optimum time of planting for scented basmati rices. Annual report 1993-94. Central Rice Research Institute, Cuttak. P. 45-47

Cruz, D. 1991. Effect of temperature during grain development on the performance and stability of cooking quality components of rice. *Jpn. J. Breed.* 39 : 299-306

Dash, C.R. and Rao, C.H.N. 1990. Effect of varying light intensities on yield and yield components of rice plant types. *Oryza* 27: 90-93

Datta, S.K. 1981. *Principles and Practices of Rice Production.* John wiley and Sons, New York, p. 681

Datta, S.K. and Zarate, P.M. 1970. Environmental conditions affecting growth characteristics, N response and grain yield of tropical rice. *Biomet.* 4: 71-89

Deepa, S. 1998. Integrated nutrient management in a rice - rice cropping system. MSc (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 94

Deka, S.C., Sood, D.R. and Gupta, K.R. 2000. Nutritional evaluation of basmati rice (*Oryza sativa* L.) genotypes. *J. Fd. Sci. Tech.* 37 : 272-276

Deosarkar, D.B. and Nerkar, S. 1993. Cooking and eating qualities of some rice varieties. *J. Maharashtra Agric. Univ.* 18: 506-507

Dhal, N.K. and Choudhary, N. 1987. Effect of planting time and fungicidal spray on sheath rot of rice. *Oryza* 24: 274-276

Dhaliwal, Y.S., Nagi, P.S., Sidhu, G.S. and Sekhon, K. 1986. Physico chemical, milling and cooking quality of rice as influenced by sowing and transplanting dates. *J. Sci. Fd. agric.* 4: 4-7

Dhiman, S.D., Nandal, D.P. and Om, H. 1997. Performance of scented and non scented rice genotypes under direct seeding and transplanted conditions. *Indian J. Agron.* 44 : 2

Dhiman, S.D., Om, H. and Singh, B. 1995. Yield stabilization of scented dwarf rice under late planting through spacing and seedling age. *Haryana agric. Univ. J. Res.* 25: 95-99

Dinesh, C. 1995. Basmati rice for Orissa. *Indian Fmg.* 45: 26-28

Dodan, D.S. and Singh, R. 1995. Effect of planting time on disease incidence. *Indian Phytopath.* 48: 185-186

Dutta, R.K., Lahiri, B.P., Khanam, S. and Raliman, S. 1999. Aroma synthesis in basmati rice in relation to temperature and nitrogen. *Indian J. Pl. Physiol.* 4: 215-218

Gangwar, K.S. and Sharma, S.K. 1998. Effect of planting date on productivity and profitability of scented rice and wheat varieties in rice-wheat system. *Indian J. Agron.* 43: 1-6

Ghildyal, B.P. and Kushevela, H.S.A. 1987. Short term meteorological studies with stress tolerant and sensitive rice cultivars. *Oryza* 24: 313-335

Giri, A.A., Dahiphale, V.V., Gunjkar, M.V. and Jadhav, A.S. 1999. Nutritional requirement of basmati rice under upland irrigated conditions on vertisols. *J. Maharashtra agric. Univ.* 24 : 301-302

Gohain, T. and Saikia, L. 1993. Effect of date of transplanting on growth and yield of rainfed low land rice (*Oryza sativa*). *Indian J. Agron.* 41: 488-490

Gomez, K.A. 1972. *Techniques for Field Experiment with Rice.* Int. Rice Res. Int., Los Banos, Philippines. p. 33

Gupta, V.K., Agarwal, K.K., Upadhyay, A.P. and Sankar, V. 2000. Effect of rainfall, number of rainy days and length of rainy season on productivity of rice crop at Jabalpur. *J. Agromet.* 2 : 61-64

Hirannaiah, M.K. Bhashyam and Ali, S.Z. 2001. An improved cooking quality test for basmati rice. *J. Fd. Sci. Tech.* 38 : 116-119

Huda, A.K.S., Ghildyal, B.P., Tomar, V.S. and Jain, R.C. 1975. Contribution of climatic variables in predicting rice yield. *Agric. Met.* 15: 17-86

IRRI. 1974. Annual Report 1973-74. International Rice Research Institute, Philippines. p. 48-63

IRRI. 1980. Effect of temperature on grain filling. Annual report. 1979-80. International Rice Research Institute, Philippines pp. 296-297

IRRI. 1981. Standard evaluation system for rice - International rice testing programme (RTP). International Rice Research Institute, Los Banos, Philippines, p. 48

Iwata, F. 1984. Heat unit concept of crop maturity. In: *Physiological aspects of dry land agriculture.* Ed. V.S. Gupta, Oxford and IBH publishing Co., New Delhi p. 328

Jackson, M.L. 1973. *Soil Chemical Analysis.* Prentice Hall of India, Pvt. Ltd. New Delhi, p. 498

Jain, R.C., Agrawal, R. and Jha, M.P. 1980. Effect of climatic variables on rice yield and its forecast. *Mausam* 31: 591-596

Jand, V., Gains, G.S. and Mavi, H.S. 1994. Effect of different dates of transplanting on biomass production and partitioning in various parts of rice crop. *Indian J. Ecol.* 21: 13-18

Jand, V., Gains, G.S. and Mavi, H.S. 1995. Effect of meteorological factors on behaviour of rice crop under Punjab condition. *Indian J. Ecol.* 22: 127-129

*Jiang, G.Z. and Zhou, F.V. 1987. The effect on yield of different sowing dates and rates for dry land rice direct sown. *Jiangsu agric. Sci.* 5: 9-10

Juliano, B.O. and Perez, C.M. 1984. Results of collaborative test on the measurement of grain elongation of milled rice during cooking. *J. Cereal Sci.* 2 : 281-292

Kamalam, J. and Havanagi, G.V. 1987. Effect of date of planting and irrigation on yield and yield attributes of rice varieties. *Indian J. Agron.* 32: 411-413

Kang,S.C and Heu, G.Y. 1976. Studies on the effect of cultural season on rice growth and yield components in Yooguan region. *Res. Rep. Rur. Dev.* Korea 18: 79-85

KAU. 1985. Identification of factors responsible for low level production of high yielding varieties of rice during mundakan season and formulation of technology for overcoming yield decline. Annual report 1984-85. Kerala Agricultural University, Trichur

Kembuchetty, N. 1978. Effect of weather on growth and yield of rice. *Ph.D. thesis,* Tamilnadu Agricultural University, p. 268

Khan, M.S. and Ali, C.A. 1985. Cooking quality of some rice varieties. *J. agric. Res.* Pakistan. 23: 231-283

Khush, G.S., Poule, C.M. and Cruz, D.N. 1979. Rice grain quality evaluation and improvement at IRRI. In *Chemical Aspects of Rice Grain Quality.* International Rice Research Institute, Los Banos, Philippines, p. 231

*Kim, C.Y., Lee, J.H. and Chung, K.Y. 1973. Influence of environmental conditions on the characteristic of aerial part of rice under different seasonal culture. *Res. Rep. Rice Dev. Korea.* 15 : 25-34

Krishnakumar, V. 1986. Agro meteorological parameters and hydronutritional management practices on rice cultivars. *Ph.D. thesis*, Tamilnadu Agricultural University, p. 277

Krishnakumar, V. and Subramanian, S. 1991. Influence of meteorological parameters on growth and yield of low land rice. *Oryza* 28: 49-54

Lalitha, K., Reddy, D.R. and Rao, S.B.N. 1999. Influence of temperature and sunshine hours on tiller production in low land rice varieties. *J. Agromet.* 1: 187-190

Latif, P.H. 1982. Differential response of two medium duration rice varieties to time of planting and graded dose of nitrogen. M.Sc. thesis. Kerala Agricultural University, Trichur, p. 149

Lenka, D. 1998. *Climate, weather and Crops in India*. Kalyani publishers. India, p. 481

*Lin, S.S. 1976. Effect of high water temperature on ecological and physiological status of second crop rice in Taiwan. *J. Agric. Assoc. China,* 95 : 24-35

Mahal, S.S., Uppal, H.S. and Mankoha, B.S. 1999. Influence of planting date and irrigation management in scented rice (*Oryza sativa* L.) varieties in trans gangetic plain region. *Envirn. Eco.* 17: 557-559

Maity, K. and Mahapatra, P.K. 1988. Response of rice varieties to planting time during the dry season. *Int. Rice Res. Newsl.* 13(4) : 15

Majid, A. and Ahmed, S. 1975. Effect of transplanting dates on paddy field and other plant characters in different rice varieties. *J. Agric. Res.* 13 (2): 447-464

Major, D.J., Johnson, D.R. and Luedders, V.D. 1975. Evaluation of eleven thermal unit methods for predicting soyabean development. *Crop Sci.* 15: 172-174

Mandal, B.K., Sainik, T.R. and Ray, P.K. 1984. Effect of age of seedling and level of nitrogen on the productivity of rice. *Oryza* 21: 225-232

Mann, R.F. 1987. 'Basmati rice : Wonder of Pakistan's Agriculture'. *Int. Rice Res. Commun. Newsl.* 36(3): 23-28

Matsubayashi, M.R., Takasi, T., Namoto, T. and Yamada, N. 1963. *Theory and Practice of Growing Rice.* Fuji Publishing Co. Ltd., Tokyo, p. 502

Matsui, T., Namuco, O.S., Ziska, H.L. and Horie, T. 1997. Effect of high temperature and CO_2 concentration on spikelet sterility in *Indica* rice. *Field Crops Res.* 51 : 213-219

Mavi, H.S. 1986. *Introduction to Agrometeorology.* Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, p. 233

Mehta, D.S., Gupta, A.P. and Panwar, D.V.S. 1995. Potassium fertilization for higher yields in scented rice. *Int. Rice Res. Newsl.* 20(3) : 21-22

*Meng, Y. and Zhou, Z. 1997. Relationship between rice grain quality and temperature during seed setting period. *Chinese J. Rice Sci.* 11: 51-54

Nagi, I. 1968. Growth and performance of rice varieties under controlled temperature and photoperiod conditions. *Int. Rice Commun. Newsl.* 12(1): 71-86

Narayanaswamy, S., Rao, Y.Y. and Ramaseshaiah, K. 1982. Effect of time and method of sowing on rice varieties in puddled soil during wet season. *Oryza* 19: 47-52

Nayak, S.K., Murty, P.S.S. and Murty, K.S. 1979. Photosynthesis and translocation in rice during ripening as influenced by different light intensities. *J. Nuclear agric. Biol.* 8: 23-25

Neild, R.E., Lagon, J. and Cardenas, A. 1983. Growing season and phenological response of sorghum as determined from simple climatic data. *Agric. Met.* 30: 35-48

Nishiyama, I. 1985. Relation between rice yield and PAR during the seed ripening stage in selected cultures in Japan. *Jap. J. Crop Sci.* 54: 8-14

Om, H., Katyal, S.K., Dhiman, S.D. and Sheoran, O.P. 1998. Physiological parameters and grain yield as influenced by time of transplanting and rice hybrids. *Indian J. Agron.* 44: 696-700

Om, M.S., Singh, O.P. and Joon, R.K. 1993. Effect of time of transplanting and spacing on basmati rice. *Haryana J. Agron.* 9: 87

Osada, A., Nara, M. and Chakrabandhu, H. 1973. Seasonal changes in growth pattern of tropical rice. *Proc. Crop Sci. Soc. Jap.* 42: 351-361

Ou, S.H. 1973. *Handbook of Rice Diseases in the Tropics.* International Rice Research Institute, Los Banos, Philippines, p. 58

Owen, P.C. 1971. The effects of temperature on the growth and development of rice. *Field Crop abstr.* 24 : 1-8

Padmaja, R.S. 1990. Influence of date of planting on high density grain yield in rice. *Oryza* 27: 101-103

Pajankar, D.S. Jibhakate, B.M., Sorte, P.N. and Gorarnnagar, H.B. 1997. Production cost of broadcasting paddy in comparison with normal and late transplanting in the puddled field. *J. Soils Crops* 7: 196-199

Palaniswamy, K.M., Kalyanikutty, T. and Sreenivasan, S. 1968. Effect of some agronomic factors on yield of few *Japonica* and *Indica* rice cultures. *Madras agric. J.* 55: 440-444

Perumal, M. 1989. Response of rice variety Lakshmi (Kayamkulam-1) to different dates of planting and plant density. M.Sc. thesis, Kerala Agricultural University, Thrichur, p. 70

Prasad, R. and Rana, R.S. 2002. Weather relation of rice blast in mid hills of Himachal Pradesh. *J. Agromet.* 4: 149-152

Radhakrishnamurthy, V., Sivakumar, M.V.K., Satyanarayana, V. and Bhushan Rao, C.H. 2000. Correlation between weather parameters and seed yield of soyabean (*Glycine max* L.) genotypes. *J. Agromet.* 2 : 101-102

Rajagopalan, K., Narayanaswamy, P. and Kumler, M.L. 1973. Yield potential of some IRRI varieties under different dates of planting at Coimbatore. *Int. Rice Commun. Newsl.* 22(2): 1-8

Rajput, R.P. 1980. Response of soyabean crop to climate and soil environment - Ph.D. thesis. Post graduate school, IARI, New Delhi, p. 222

Ramaiah, N.V., Raghavaiah, R., Reddy, S.N., Raju, M.S. and Singh, B.G. 1987. Effect of time of planting and nitrogen in rice. *The Andra agric. J.* 34: 1-4

Ramdoss and Subramanian, S. 1980. Influence of sowing time on yield attributes and yield of rice variety Periyar. *Madras agric. J.* 67: 375-378

Ramesh, B. and Singh, B. 1999. Contribution of different tillers within a plant to grain yield of rice. *Oryza* 36: 228-233

Rani, S.N., Thaper, B.K., Lodh, S.B., Sidhu, G.S., Chaudhary, D. and Jena, K.K. 1996. Breeding for quality rices for aromatic and export market. Report of the INGER monitoring visit on Fine Grain Aromatic Rice in India, Iran, Pakistan and Thailand on Sept 21 - Octo 10. International Rice Research Institute, Philippines, p. 45-88

Rao, B.C.H., Ikramullah, M. and Murthy, V.R. 2000. Influence of time of planting on grain yield of scented rice varieties. *Crop Res.* 20 : 179-181

Rao, K.N., Raman, C.R.V. and Jayanthi, S. 1971. Relationship between evaporation and other meteorological factors. *Indian J. Met. Geophys.* 23: 327-333

Rao, K.S., Moorthy, B.T.S., Das, A.B. and Lodh, S.B. 1996. Effect of time of transplanting on grain yield and quality traits of basmati type scented rice (*Oryza sativa*) varieties in coastal Orissa. *Indian J. agric. Sci.* 66: 333-337

Rao, K.S., Moorthy, B.T.S., Lodh, S.B. and Sahoo, K. 1993. *Indian J. Agric. Sci.* 63: 467-472

Rao, N.N.P. and Deb, A.R. 1974. Influence of sunshine hours on productivity of rice. *Rice* 24: 167-177

Rao, P.S. 1995. Yield and high density grain as influenced by crop density and N level in scented rice. *Madras agric. J.* 82 : 108-112

Rao, P.S.P. and Padhi, G. 1988. Weather factors influening outbreak of yellow stem borer on rainy season (*Oryza sativa*). *Indian J. agric. Sci.* 56: 494-495

RARS, 1981. Annual report (1980-81). Regional Agricultural Research Station, Pattambi, Kerala, India p. 33-35.

Reddy, G.V. and Reddy, P.S. 1986. Effect of time of planting on yield of four Nellore rice varieties during wet season. *Oryza* 23: 190-193

Reddy, S.K. and Reddy, B.B. 1992. Effect of time of planting, spacing and age of seedling on flowering and duration of Surekha rice. *Oryza* 29: 157-159

Reddy, S.N. and Narayana, P. 1981. Effect of age of seedling at different dates of transplanting on yield component and yield of rice. *Res. Bull. Marathwada agric. Univ.* 5: 18-21

Rohilla, R., Singh, V.P., Singh, V.S., Singh, R.K. and Khush, G.S. 2000. Crop husbandry and environmental factors affecting aroma and other quality traits. *Int. Rice Res. Inst.*, Philippines, pp. 201-213

Sahu, C. and Murty, K.S. 1976. Seasonal influence on dry matter production, N uptake and yield in rice variety. *Indian Agric.* 1: 43-50

Sahu, C., Rao, C.H.N. and Murty, K.S. 1983. Influence of temperature and solar radiation on growth and yield of rice. *Oryza* 20: 51-54

Saikila, M., Ibrahim, S.M., Anandakumar, C.R., Backiyarani, S. and Bastian, D. 1999. Grain quality characteristics of aromatic and non aromatic rice cultivars. *Int. Rice Res. Notes* 17-18

Samui, R.P. 1999. A note on weather and rice yield relationship in some stations in India. *J. Trop. agric.* 36: 73-75

Saroja, R. and Raju, N. 1985. Effect of planting time on rice panicle bug incidence. *Int. Rice Res. Newsl.* 10(3): 17

Sastri, A.S. 1986. Effect of onset of monsoon on length of growing season and productivity of rainfed rice in Madya Pradesh. *Int. Rice Res. Newsl.* 11(3): 26

Sastry, P.S.A. and Chakravarthy, N.V.K. 1982. Energy summation indices for wheat crop in India. *Agric. Met.* 27 : 48-48

Satake, T. and Yoshida, S. 1978. High temperature induced sterility in *Indica* rices at flowering. *Jap. J. Crop Sci.* 47: 6-17

Sato, K. 1972. Growth response of rice plant to environmental conditions. *Proc. Crop Sci. Soc. Jap.* 41 : 388-393

Shankar, V. and Gupta, B.R.D. 1981. A correlation study of the height of the paddy crop with some weather elements at a few stations in India. *Agric. Met.* 23: 137-142

Sidhu, G.S., Gill, S.S., Mahi, S.S. and Bharaj, T.S. 1992. Basmati-385 approved for cultivation in Punjab, India. *Int. Rice Res. Newsl.* 17(2): 5

Singh, B.N., Sahu, S.P., Prasad, Y. and Singh, R.S. 1986. Seedling age in relation to sheath rot occurance in rice. *Int. Rice Res. Newsl.* 11(2): 26

Singh, B.N., Srivastava, S.P. and Hazarika, U.K. 1984. Effect of continuous flow of irrigation water on growth and yield of rice growing at higher altitudes. *Indian J. Agric. Sci.* 54: 201-203

Singh, M.V., Tripathy, H.N. and Tripathy, H.P. 1997. Effect of nitrogen and planting dates on yield and quality of scented rice. *Indian J. Agron.* 42 : 602-606

Singh, R. 1988. Effect of prevailing temperature and humidity on rice army worm reproduction during upland crop season. *Int. Rice Res. Newsl.* 13(3): 40

Singh, R.K. and Singh, U.S. 1997. Indigenous scented rices, farmer's perception and commitment. Paper presented at International Conference on creating Innovation and networking at Grass roots, Jan 14-17 IIM, Hyderabad, India

Singh, R.S., Ghosh, D.C. and Srivastava, V.C. 1991. Studies on production factors limiting yield attributes and yield of rainfed upland rice. *Indian J. Agron.* 36: 159-164

Singh, S., Rao, V.V.M. and Singh, D. 1957. Influence of climate and date of sowing on the yield of wheat crop. *Vayumandal* 25 : 52-59

Singh, S.P., Pillai, K.G., Pati, D. and Rani, N.S. 1993. Influence of time of planting on grain yield and quality of dwarf scented rice varieties. *Oryza.* 30: 285-288

Singh, S.P., Pillai, K.G., Pati, D. and Sobha Rani, N. 1995. Effect of planting date on grain yield and quality of semidwarf scented rice varieties. *Int. Rice Res Notes* 20(2): 24

Singh, S.P., Rani, N.S., Sreedevi, B. and Krishnaveni, B. 1999. Effect of planting dates on grain yield and quality of dwarf scented rice varieties. *Oryza* 36 : 388-390

Singh, V.P. 2000. The Basmati rice of India. *Aromatic Rices.* Oxford and IBH publishing Co. Pvt. Ltd., New Delhi p. 275

Singh, V.S., Rohilla, R., Singh, A., Tiweri, S.N. and Singh, H.M. 2000. Plant protectin in Aromatic Rices (In) *Aromatic Rices.* Oxford and IBH publishing Co. Pvt. Ltd., New Delhi. p. 275

Singhania, R.A. and Singh, S. 1991. Effect of manuers and nitrogen fertilizers on the phosphorus uptake and grain yield of paddy. *Curr. Res.* 20: 249-250

Sreedharan, C. 1975. Studies on the influence of climatogical factors on rice under different water management practices. *Ph.D thesis.* Orissa University of Agriculture and Technology, Bhubaneswar. p. 225

Sreedharan, C. and Vamadevan, V.K. 1981. Fertilization of rice as influenced by weather conditions. *Trop. Ecol.* 22: 246-255

Sreelatha, P. 1989. Influence of weather parameters on growth and yield of rice variety Jaya. M.Sc. Thesis, Kerala Agricultural University, Trichur, p. 91

Sreenivasan, P.S. and Banerjee, I.R. 1978. Behaviour of the Co-25 variety of rice under two environments. *Agric. Met.* 19: 189-202

*Stansel, J.W. 1975. Effective utilization of sunlight. *Texas Agric. Expt. Stn. Res. Monograph* 4: 43-50

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Curr. Sci.* 25 : 259-260

Subha, K.M. 2000. Effect of sowing date and quality traits in Basmati-370. MSc thesis, Tamilnadu Agricultural University. p. 111

*Suge, H. and Takairin, H. 1982. Effect of wind on growth of rice and barley plants. *Rep. Inst. Agric. Res.* 33: 1-14

Suharto, H. and Noch, I.P. 1987. Effect of transplanting date on leaf folder and rice bug infestation at Kiningari, West Java. *Int. Rice Res. Newsl.* 12(3): 27

Sujathamma, P., Rao, G.P. and Rajasekhar, D. 2001. Nitrogen dynamics in rice - groundnut cropping system. *Andhra agric. J.* 48: 223-226

Thakur, R.B., Pandeya, S.B. and Dwivedi, P.K. 1996. Effect of time of planting on performance of scented rice. *Oryza* 33: 107-109

Thakur, R.B., Singh, S.K., Jha, G. and Choudhary, S.K. 1997. Nitrogen nutrition in dwarf scented rice. *J. Appl. Biol.* 7: 28-29

Theetharappan, T.S. and Palaniappan, S.P. 1984. Optimum seedling age for transplanting short duration rice. *Int. Rice. Res. Newsl.* 9(2): 29

Tomar, J.B. 1987. Analysis of genetic components of generation mean for some quality characters in rice. *Oryza* 24: 112-118

Trivedi, K.K. and Kwatra, K.L. 1987. Effect of date of transplanting and hill spacing on growth and yield of rice. *Rice Abstr.* 10: 111

Uppal, H.S. and Bali, A.S. 1997. Quality of basmati rice kernels in relation to irrigation and planting date. *J. Res. Punjab agric. Univ.* 34: 251-258

Uthamaswamy, S. and Karuppachamy, P. 1986. Management of rice gall midge with reference to time of planting and varietal resistance. *Madras agric. J.* 73: 146-150

Venkataraman, S. and Krishnan, A. 1992. Crops and weather. Indian Council of Agricultural Research, Krishi Anusandhan Bhavan, Pusa, New Delhi, p. 558

Venkateswarlu, B., Koteswara Rao and Rao, A.V. 1976. Canopy analysis of the relation between leaf area index and productivity of low land rice (*Oryza sativa* L.) *Pl. Soil* 45: 45-46

Venkateswarlu, B., Pasad, V.V.S.S. and Rao, A.V. 1977. Effect of light intensity on different growth phases in rice (*Oryza sativa* L.) *Pl. Soil* 47: 37-47

Vergara, B.S. and Chang, T.T. 1985. The flowering response of rice plant to photoperiod. *Int. Rice Res. Tech. Bull.* p. 75

Vergara, B.S., Chu, T.M. and Jispeias, R.N. 1970. Effect of temperature on the anthesis of IR8 rice. *Int. Rice. Commun. Newsl.* 19(3) : 11-17

Verma, R.S. and Singh, M. 1998. Studies on growth development pattern and yield of rice under different sowing dates. *Indian J. Agron.* 33 : 193-195

Vidhyasekharan, P. and Lewin, H.D. 1986. Forecasting Tungro (RTV) epidemic in Tamilnadu. *Int. Rice Res. Newsl.* 11(2): 36

Viswambharan, K., Rajaram, K.P., Alexander, D. and Rajappan, N. 1989. Factors causing winter yield decline in high yielding varieties. *Int. Rice Newsl.* 12(2): 12

Vittum, M.T., Dethier, B.E. and Lesser, R.C. 1965. Estimating growing degree days. *Proc. Am. Soc. Hort. Sci.* 87 : 449-452

Vivekanandan, P., Giridharan, S. and Narasimhan, V. 1995. Reaction of some scented rice hybrids to brown spot disease. *Madras Agric. J.* 82: 327

172029

*Wada, S., Kunhara, Y. and Houna, A. 1973. Effect of some environmental factors during heading stage in the fertility of grains in rice plant. *Bull. Hokkaido Prefetwal agric. Expt. Stn.* 3: 33-35

*Wang, X.Q. and Liu, G.Y. 1991. Effect of sowing date on the yield, growth and development of target populations of direct sown rice. *J. Shanhai Agric. Coll.* 9: 51-57

Yau, M., Huushen, L., Chu, C. and Chuan, J. 2000. The applicability of DSSAT model to predict the production of rice and to evaluate the impact of climate change. *J. Korean Crop Sci. Soc.* 22: 12-15

Yoshida, S. 1972. Physiological aspects of grain yield. *Ann. Rev. Pl. Physiol.* 23:437-464

Yoshida, S. 1973. Effect of temperature on growth of the rice plant (*Oryza sativa* L) in a controlled environment. *Soil Sci. Pl. nutr.* 19: 299-310

Yoshida, S. 1981. *Fundamentals of Rice Crop Science.* International Rice Research Institute, Los Banos, Philippines, p. 269

Yoshida, S. and Parao, F.T. 1976. Climatic influence on yield and yield components of low land rice in the tropics. *Climate and Rice,* IARI, Philippines p. 494

*Zhilin, L., Sarkar, R.S., Nayak, S.K. and Ravi, I. 1997. Physiological effect of nitrogen application in aromatic rice. *J. South China agric. Univ.* 18: 13-17

* Originals not seen

PERFORMANCE OF BASMATI RICE (*Oryza sativa* L.) VARIETIES AS INFLUENCED BY DATE OF PLANTING

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Abstract of the
Thesis submitted in partial fulfillment of the requirement
For the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2002

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ABSTRACT

A field experiment was conducted at the Instructional Farm of the College of Agriculture, Vellayani during the second crop season of 2001 to study the performance of basmati rice varieties under different dates of planting.

The experiment was laid out in strip plot design with three replications. The treatments included four varieties (Pusa basmati-1, Haryana basmati, Kasturi and Basmati-370) and four dates of planting (October 10, October 23, November 5 and November 18).

The results of the experiment revealed that varieties and different planting dates had significant influence on most of the biometric and yield attributing characters of basmati rice. Among the varieties Pusa basmati-1 recorded the lowest height and possess good cooking qualities but it was highly susceptible to sheath blight disease. Among the varieties Kasturi matured early and was resistant to sheath blight disease. Grain yield was also higher for Kasturi as it has more panicle weight and thousand grain weight and also possess excellent cooking qualities as that of Pusa basmati-1. Eventhough basmati-370 recorded maximum height, LAI and DMP, this variety was susceptible to lodging which decreased the grain yield while Haryana basmati was inferior in all quality aspects. Earlier planting (10^{th} October) increased the grain yield and yield attributing characters and quality aspects.

Agrometeorological studies revealed that early planted crop took more number of growing degree days, HTU and PTU. Eventhough the growth duration was more for early planted crop, it produced the highest grain yield. Correlation

studies indicated that earlier planted crop received sufficient rains which positively influenced all the yield attributing characters resulting in higher yield while late planted crop experienced a high maximum temperature and wind which was negatively correlated with yield. There was a positive correlation between duration, minimum temperature, relative humidity, sunshine hours and heat units and a negative correlation with maximum temperature and wind. Correlation between weather parameters and sheath blight intensity also revealed a positive correlation between disease incidence and maximum temperature, relative humidity and rainfall.

- Economic analysis showed that planting of Kasturi on 10th October gave maximum net returns and BCR.

APPENDICES

Appendix I

Weather data during the entire crop growth period

Standard week	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8
Maximum temperature (°C)	30.0	29.5	30.3	31.0	30.4	29.7	30.5	30.5	31.0	30.6	31	31	31.4	31	30.7	31	30.2	31.5	32.0	32.2
Minimum temperature (°C)	23.7	24.0	24.0	24.2	23.7	23.1	23.4	23.2	22.9	20.0	22.3	23.5	23.0	22.9	19.5	23.5	23.0	22.5	22.4	21.3
Rainfall (mm)	14.2	52.6	95.7	Nil	54.2	14.6	37.9	Nil	8.6	Nil	3.7	8.6	Nil	3.7	8.3	Nil	Nil	Nil	Nil	Nil
Relative humidity (%)	85.3	85.1	81.4	81.1	81.8	84.1	81.9	80.3	81.1	76.2	82	79.5	80.3	78.4	76.6	76.6	78.3	77.9	75.8	76.9
Total sunshine hours	39.2	37.8	46.2	44.8	44.8	23.8	50.4	55.3	61.6	46.2	42.7	60.2	62.3	63.0	49.7	46.2	35.2	64.7	67.3	70.2
Wind speed (km hr^{-1})	6.4	5.7	5.4	4.6	6.3	4.6	4.6	6.3	5.7	5.4	5.7	5.7	5.7	6.8	6.9	5.1	4.9	6.3	7.1	8.3
Evaporation (mm)	4.8	3.0	3.0	3.1	2.8	3.1	2.4	3.3	2.9	2.7	3.1	2.4	2.9	2.7	2.8	3.0	2.8	3.1	3.2	3.1

Appendix II

Mean maximum temperature (^{0}C) during different growth stages of basmati rice varieties under different dates of planting

Stage of crop	Varieties	Date of planting			
		d_1	d_2	d_3	d_4
Vegetative	v_1	30.34	30.50	30.58	30.74
	v_2	30.36	30.48	30.68	30.63
	v_3	30.21	30.49	30.46	30.88
	v_4	30.21	30.48	30.46	30.88
Reproductive	v_1	30.86	30.87	31.13	30.73
	v_2	30.63	31.10	31.03	30.79
	v_3	30.50	30.72	30.86	30.95
	v_4	30.50	30.44	30.92	31.03
Maturity	v_1	31.03	31.02	30.88	31.48
	v_2	31.08	30.84	30.97	31.75
	v_3	30.83	31.13	30.93	31.49
	v_4	30.83	31.22	30.87	31.38

Appendix III

Mean minimum temperature during different growth stages of basmati rice varieties under different dates of planting

Stage of crop	Varieties	Date of planting			
		d_1	d_2	d_3	d_4
Vegetative	v_1	23.63	23.06	22.76	22.70
	v_2	23.22	22.92	22.79	22.65
	v_3	23.78	23.56	22.72	22.63
	v_4	23.78	23.50	22.72	22.55
Reproductive	v_1	21.73	21.93	23.13	21.96
	v_2	21.78	23.21	21.80	23.26
	v_3	23.00	22.58	21.73	22.19
	v_4	23.00	21.76	22.63	21.80
Maturity	v_1	22.23	22.48	22.28	22.30
	v_2	23.76	22.38	22.70	22.35
	v_3	21.82	22.30	22.62	22.67
	v_4	21.82	22.40	22.44	22.54

Appendix IV

Total rainfall (mm) during different growth stages of basmati rice varieties under different dates of planting

Stage of crop	Varieties	Date of planting			
		d_1	d_2	d_3	d_4
Vegetative	v_1	277.80	115.30	127.30	58.50
	v_2	294.40	202.40	115.30	46.50
	v_3	255.00	211.00	115.30	20.60
	v_4	255.00	211.00	115.30	58.50
Reproductive	v_1	12.30	12.00	8.30	Nil
	v_2	3.70	11.0	Nil	Nil
	v_3	46.50	3.70	12.00	12.00
	v_4	46.50	3.70	12.00	Nil
Maturity	v_1	8.30	8.30	Nil	Nil
	v_2	3.70	Nil	Nil	Nil
	v_3	12.00	12.00	8.30	Nil
	v_4	12.00	8.30	Nil	Nil

Appendix V

Mean relative humidity (%) during different growth stages of basmati rice varieties under different dates of planting

Stage of crop	Varieties	Date of planting			
		d_1	d_2	d_3	d_4
Vegetative	v_1	82.90	80.92	80.86	79.96
	v_2	78.81	80.30	80.90	80.19
	v_3	82.96	81.37	80.77	80.16
	v_4	82.96	81.67	80.90	80.17
Reproductive	v_1	79.76	79.23	73.86	77.20
	v_2	79.48	79.75	78.83	78.07
	v_3	81.10	79.68	81.08	79.40
	v_4	81.10	79.10	80.60	78.43
Maturity	v_1	78.70	78.65	77.48	77.10
	v_2	78.23	78.36	77.68	76.86
	v_3	79.88	78.56	78.16	77.23
	v_4	79.88	78.70	77.48	77.10

Appendix VI

Total bright sunshine hours during different growth stages of basmati rice varieties under different dates of planting

Stage of crop	Varieties	Date of planting			
		d_1	d_2	d_3	d_4
Vegetative	v_1	381.50	326.90	324.80	441.70
	v_2	433.50	265.30	282.00	378.70
	v_3	279.60	280.90	280.10	363.20
	v_4	279.60	326.90	282.00	316.40
Reproductive	v_1	150.50	149.10	185.50	158.90
	v_2	78.80	83.40	143.60	107.00
	v_3	167.30	119.60	124.50	159.50
	v_4	167.30	88.90	165.20	175.00
Maturity	v_1	235.20	243.90	194.10	283.60
	v_2	224.50	178.00	124.10	202.20
	v_3	274.40	277.90	336.30	237.40
	v_4	274.40	235.20	194.10	283.60

Appendix VII

Mean wind velocity (km hr^{-1}) during different growth stages of basmati rice varieties under different dates of planting

Stage of crop	Varieties	Date of planting			
		d_1	d_2	d_3	d_4
Vegetative	v_1	5.51	5.35	5.53	5.74
	v_2	5.30	5.48	5.59	5.45
	v_3	5.25	5.90	5.92	5.94
	v_4	5.45	5.36	5.48	5.57
Reproductive	v_1	5.80	5.60	6.06	6.27
	v_2	6.12	5.35	6.40	5.33
	v_3	5.53	5.36	5.46	5.90
	v_4	5.53	5.55	5.70	6.47
Maturity	v_1	6.28	6.13	5.93	6.34
	v_2	6.05	6.48	6.88	7.23
	v_3	5.86	6.47	5.67	6.65
	v_4	5.86	6.47	5.93	6.34

Appendix VIII

Accumulated Heliothermal unit (HTU) during different growth stages of basmati rice varieties under different dates of planting

Stage of crop	Varieties	Date of planting			
		d_1	d_2	d_3	d_4
Vegetative	v_1	6274.03	5300.43	5191.89	7545.56
	v_2	7099.72	4287.29	4721.88	6373.99
	v_3	4654.06	4554.19	4562.47	6214.27
	v_4	4654.06	5325.56	5392.14	5400.13
Reproductive	v_1	2417.12	2451.09	3115.31	3998.30
	v_2	856.95	984.90	1739.91	1825.92
	v_3	2812.49	2042.91	2058.81	3945.91
	v_4	2812.49	1517.13	2338.41	2876.45
Maturity	v_1	4731.44	4205.24	4111.22	3108.16
	v_2	3518.53	2803.88	2110.35	1067.77
	v_3	4724.28	4776.84	3516.02	2065.04
	v_4	4724.28	2385.25	1892.46	3640.39