INFLUENCE OF CROP GEOMETRY ON THE GROWTH AND YIELD OF RICE VARIETY JAYA

By

K. E. USHA

THESIS

submitted in partial fulfilment of
the requirement for the degree

Master of Science (Agronomy)

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur
1985

DECLARATION

I hereby declare that this thesis entitled "Influence of crop geometry on the growth and yield of rice variety 'Jaya'" is a bonafide record of work done by me during the course of research work and 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.

College of Horticulture,
Vellanikkara,
11--5--1985.

Usha

Usha. K. E.

CERTIFICATE

Certified that this thesis entitled "Influence of crop geometry on the growth and yield of rice variety 'Jaya'" is a record of research work done independently by Smt. Usha. K. E., 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.

11/5/85

Vellanikkara,
11 --5--1985.

Dr. P. Balakrishna Pillai
Professor of Agrometeorology.

CERTIFICATE

We, the undersigned members of the Advisory Committee of Smt. Usha. K.E., a candidate for the degree of Master of Science in Agriculture with major in Agronomy agree that thesis entitled "Influence of crop geometry on the growth and yield of rice variety 'Jaya'" may be submitted by Smt. Usha. K.E., in partial fulfilment of the requirements for the degree.

11-5-85

(Dr. P. Balakrishna Pillai)
(Advisor and Chairman)

(Dr. C. Sreedharan)
Member

(Sri. [illegible] Nair)
Member

11.5.85
(Dr. A. S. Rao)
Member

This thesis is humbly dedicated
to the lotus feet of my God
without whose grace and
blessings this work would
not have been possible.

ACKNOWLEDGEMENTS

It is with a deep sense of gratitude that I acknowledge my great indebtedness to Dr. P. Balakrishna Pillai, Professor, Head of the Department of Agrometeorology, College of Horticulture, Vellanikkara for suggesting the problem and for his sustained interest, inspiring guidance, critical suggestions and constant encouragement throughout the course of the present investigation.

I had the unique previlege of getting the advice and guidance of the members of the Advisory Committee at every stage of this work. Dr. C. Sreedharan, Professor and Head, Department of Agronomy, College of Horticulture has taken keen interest in my work with invaluable guidance and constructive criticims during the period of the study. I express my gratitude to him.

Sri. N. Rajappan Nair, Associate Director, Regional Agricultural Research Station, Pattambi was gracious enough to render me his heart-felt co-operation and help in conducting the experiment in the fields at Pattambi. The guidance he gave me and the supervision he did on my work there were far beyond the call of duty. I would like to record my deep gratitude for him.

I owe a profound sense of gratitude to Dr. P. K. Gopalakrishnan, Associate Dean, College of Horticulture and the Kerala Agricultural University for providing the necessary facilities to carry out the study.

I thankfully acknowledge my gratitude to Dr. A. S. Rao, Scientist, Centre for Water Resource Development and Management, Calicut for his inspiring suggestions and constructive criticisms. I express my sincere thanks to Mr. M. Sethumadhavan, Department of meteorology for the help he has often rendered.

I wish to place on record my sincere thanks to the staff members of the Regional Agricultural Research Station, Pattambi for their help and co-operations during the course of this investigation.

At the various stages of the work, the help and assistance of the staff and students of the Department of Agronomy and my friends whose co-operation was in no small way helpful for the successful completion of my work. I shall ever be grateful to them.

I thankfully acknowledge the Junior Felloship received from the Indian Council of Agricultural Research.

I wish to record my sincere thanks to Kum. Rajani Gopal, who took lot of pains in typing this manuscript in proper way and Chirayath Commercial Institute, Mullakkara for providing necessary facilities for the typing.

Last, but not the least, the constant and sustained encouragement I got from my husband, parents and relatives is gratefully acknowledged.

I believe that I had all blessings of Him and I am fully satisfied that I could do as much as this in this field.

Usha

Usha. K.E.

CONTENTS

1. Introduction .. 1 - 3

2. Review of Literature .. 4 - 23

3. Materials and Methods .. 24 - 32

4. Results .. 33 - 97

5. Discussion .. 98 - 112

6. Summary and Conclusions .. 113 - 115

7. References .. 116 - 126

8. Appendices .. I - XXIV

****

LIST OF TABLES

1. Table 1. Height of plant on 30th day after planting (cm)

2. Table 1.(a) Combined effect of Spacing between plants and spacing between alleys on height of plant on 30th day after planting (cm).

3. Table 2. Height of plant on 60th day after planting (cm)

4. Table 3. Height of plant at the time of harvest (cm)

5. Table 3.(a) Combined effect of spacing between plants and spacing between alleys on height of plant at the time of harvest (cm).

6. Table 4. Number of tillers on 30th day after planting.

7. Table 5. Number of tillers on 60th day after planting.

8. Table 5.(a) Combined effect of spacing between plants and spacing between alleys on number of tillers on 60th day after planting.

9. Table 6. Number of tillers at the time of harvest.

10. Table 7. Leaf area index on 40th day after planting.

11. Table 7.(a) Combined effect of spacing between plants and spacing between alleys on leaf area index on 40th day after planting.

12. Table 8. Leaf area index on 75th day after planting.

13. Table 8(a) Combined effect of spacing between plants and spacing between alleys on leaf area index on 75th day after planting.

14. Table 9. Leaf area index on 90th day after planting.

15. Table 9.(a) Combined effect of spacing between plants and spacing between alleys on leaf area index on 90th day after planting.

16. Table 10. Leaf area index at the time of harvest.

17. Table 11. Number of productive tillers

18. Table 12. Length of panicle (cm).

19. Table 12.(a) Combined effect of spacing between plants and spacing between alleys on length of panicle (cm).

20. Table 13. Number of grains per panicle.

21. Table 13.(a) Combined effect of spacing between plants and spacing between alleys on number of grains per panicle.

22. Table 14. Thousand grain weight (g).

23. Table 14.(a) Combined effect of spacing between plants and spacing between alleys on thousand grain weight (g).

24. Table 15. Grain yield (Kg/ha).

25. Table 16. Straw yield (Kg/ha).

26. Table 16.(a) Combined effect of spacing between plants and spacing between alleys on straw yield (Kg/ha).

27. Table 17. Drymatter Production (Kg/ha).

28. Table 17.(a) Combined effect of spacing between plants and spacing between alleys on drymatter production (Kg/ha).

29. Table 18. Grain-Straw ratio.

30. Table 18.(a) Combined effect of spacing between plants and spacing between alleys on grain-straw ratio.

31. Table 19. Nitrogen Content (%).

32. Table 19.(a) Combined effect of spacing between plants and spacing between alleys on nitrogen content (%).

33. Table 20. Phosphorous content (%).

34. Table 20.(a) Combined effect of spacing between plants and spacing between alleys on phosphorous content (%).

35. Table 21. Potassium content (%).

36. Table 21.(a) Combined effect of spacing between plants and spacing between alleys on potassium content (%).

37. Table 22. Uptake of Nitrogen (Kg/ha).

38. Table 23. Uptake of Phosphorous (Kg/ha).

39. Table 23.(a) Combined effect of spacing between plants and spacing between alleys on the uptake of Phosphorous (Kg/ha).

40. Table 24. Uptake of Potassium (Kg/ha).

41. Table 24.(a) Combined effect of spacing between plants and spacing between alleys on the uptake of potassium (Kg/ha).

42. Table 25. Average day time variation of albedo on different treatments on 14-12-1983.

43. Table 26. Average day time variation of albedo on different treatments on 28-12-1983.

44. Table 27. Average day time variation of albedo on different treatment on 11-1-1984.

45. Table 28. Average day time variation of albedo on different treatments on 25-1-1984.

46. Table 29. Average day time variation of albedo on different treatments at harvest (on 7-2-1984

47. Table 30. Total radiation, reflected radiation and albedo at different growth stages of the rice crop in different orientations.

LIST OF ILLUSTRATIONS.

Fig. 1. Weather conditions during the crop season.

Fig. 2. Lay out plan.

Fig. 3. Leaf area index at various growth stages.

Fig. 4. Yield of grain and straw-Effect of orientation.

Fig. 5. Average day time variation of albedo on 14-12-1983. Effect of row orientation.

Fig. 6. Average day time variation of albedo on 14-12-1983. Effect of spacing.

Fig. 7. Average day time variation of albedo on 11-1-1984. Effect of orientation.

Fig. 8. Average day time variation of albedo on 11-1-1984. Effect of spacing.

Fig. 9. Total radiation, reflected radiation and albedo at different growth stages in different orientation.

Fig. 10. Leaf area index and albedo at different growth stages in different orientation.

******

INTRODUCTION

INTRODUCTION

Rice is the most important food crop of Kerala occupying an area of 7.78 lakh hectares. Out of this, 3.52 lakh hectares are cultivated during the second crop season. The second crop, which covers 45 percent of the area, contributes to 43 percent of the production. The average yield of rice in this season is reported to be less than that of the first and the third crop seasons. Since the cost of inputs like fertilisers, weedicides, insecticides and irrigation is increasing tremendously, it is time to make efforts to increase the yield with minimum of inputs through better crop management and by providing proper environment to the crop during its growth and development period.

Rice production during this season is affected by the integral effects of climatic factors like rainfall, solar radiation, temperature and relative humidity. Maximum yield is possible only through providing the crop a suitable combination of these factors in the optimum range. Solar radiation is one of the most important factors that determine rice yields (Van Ittersun, 1971). At the reproductive stage it has the greatest effect on grain yield;

at the ripening stage the next highest effect and at the vegetative stage an extremely small overall effect (Sato,1956). Crop photosynthesis in the field is primarily determined by incident solar radiation, photosynthetic rate per unit leaf area, leaf area index and leaf orientation. High solar radiation is a prerequisite for high rates of photosynthesis. It has been observed that the crop canopy is well above the light saturation capacity of leaves, while the lower leaves are not photosynthesising actively for want of light. By selecting proper crop geometry it is possible to alter the radiation penetration and thereby change the micro-environment of the crop and increase the light availability to lower leaves for photosynthesis. The light utilising effeciency of leaves can be increased to a large extent for increasing crop yield and it does not involve any extra expenditure on the farmers. Keeping this in view studies were conducted with the rows oriented in four geographical directions.

Plant population increases the crop yield with increase in number of plants per unit area until the state, when light penetration in the thick crop canopy does not become a limiting factor and when competition among the crop plants for nutrients is not there. Experiments conducted at IRRI have shown that each variety of rice has an optimum spacing and that closer spacing is more conducive to obtain better yields especially for high yielding strains (Tanaka et al. 1966). The studies conducted by Nair (1968) showed a general trend in favour of closer spacing for dwarf indicas. Closer spacing assures a sufficiently large leaf area index for maximum photosynthesis and the production of a large number of panicles to meet the requirements for better yield. There is very little information regarding the spacing given between alleys for the variety 'Jaya' under Kerala conditions. Therefore, plant population was introduced as a factor along with different spacing between alleys and crop orientation.

The present investigation was therefore undertaken with the following objectives in view:

1. To find out the best crop orientation, optimum spacing between plants and optimum spacing between alleys for the rice variety 'Jaya'.
2. To study the variation of albedo in different row orientation at different growth stages of rice crop.
3. To study the uptake of nutrients in different row orientations, spacing between plants and that between alleys.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Rice production is considerably influenced by environmental factors of which weather factors are the most important. Climate directly influences the physiological processes that affect the rice plant's growth, development and grain formation. Radiation, temperature and rainfall are the main factors that influence the grain yield of rice directly. Experiments conducted at IRRI showed that the solar radiation was positively correlated with the grain yield. The penetration and interception of solar radiation greatly depend upon the crop orientation. Spacing is also an important production factor in transplanted rice. A uniform stand containing an optimum plant population is essential for proper crop development and high grain yield.

The literature pertaining to the studies has been reviewed under the following subheads:

1. Radiation and crop growth
   a) Radiation regime of plant eanopy
   b) Albedo
2. Photosynthesis and yield of rice
3. Effect of row orientation
4. Effect of spacing on the growth and yield of rice

1. Radiation and crop growth

Murata (1964) and Hanyu (1966) reported that rice yield increases with solar radiation during the ripening period. Stansel *et al*. (1965) suggested that the rice plant's most critical period of solar energy requirement is from panicle initiation to about 10 days before maturity.

Pendleton *et al*. (1967) found that light appears to be the primary ecological factor, limiting the grain yield of maize crop when grown under high productive conditions.

Intensive research at IRRI has demonstrated that the quantity of solar radiation has a profound influence on rice yield particularly during the last 30 to 45 days of the ripening period (Moomaw *et al*. 1967). Subsequent IRRI research indicated that the increase in drymatter between panicle initiation and harvest was highly correlated with grain yield (De Datta *et al*. 1968).

Anderson (1969) observed that net radiation within a plant stand was markedly affected by stand geometry.

Goudrain (1971) found that the fraction of radiation intercepted by a layer, with certain leaf area is proportional to the average projection and inversely proportional to the sine of the inclination of the incident radiation.

When solar radiation is incident on a well developed rice crop, about 20 percent of the total radiation is reflected into the sky (Kishida, 1973).

In an experiment by Yoshida and Parao (1976), shading during the vegetative stage had little effect on grain yield whereas shading during the reproductive stage had even greater effect than that during grain ripening. During the reproductive stage solar radiation affects spikelet number per square meter, and during ripening it affects filled spikelet percentage. Venketeswarlu et al. (1977) observed that yields were progressively reduced with low light intensity appearing in succession at different growth phases, the effect being more critical during the ripening phase.

Vanderbilt et al. (1979) found that increased light intensities increased wheat yields till plant reached its light saturation.

Evans and De Datta (1979) correlated yield with cumulative radiation for various periods working either forward from the date of planting or backward from the date of maturity. The slight effect on yield, of radiation in the vegetative period, and the importance of radiation both before and just after flowering, are evident.

a) Radiation regime of plant canopy

The importance of the light factor in relation to drymatter production in plant communities was first elucidated by Boysen Jensen (1932). He stressed the importance of shape of canopy and of inclination of leaves in relation to light utilisation.

Monsi and Saeki (1953) observed that the relative radiation intensity decreases exponentially with increasing leaf area.

Theoretical analysis of relations between foliage and its light interception led to the important concept of 'Optimum leaf area index' (Donald and Davision, 1958).

Tsunoda (1959) investigated 3 attributes of leaves - form, inclination and arrangement in high yielding varieties of sweet potato, soybean and rice.

Warren Wilson (1959) devised the point-quadrat method to estimate leaf area index, inclination of leaves and leaf arrangement. The light interception in the direction of incidence is greater with a regular arrangement of leaves, and smaller when the leaves are clustered than when they are randomly arranged.

From the analysis of evapotranspiration structure of rice field it was found that net radiation decreases exponentially with leaf area (Uchijima, 1961).

Murata (1961) and Tsunoda (1964) pointed out the importance of canopy structure for increasing rice yield.

Denmead et al. (1962) observed that net radiation is of basic importance in describing physical environment of the crop since it represents, among other things, the energy available for growth. Knowledge of spatial distribution of net radiation in a crop canopy can provide information about the possible magnitude of evaporation, transpiration and photosynthesis as well as information about the regions within the crop canopy which are most active in these processes.

Isobe (1962) showed that the transmission coefficient of a rice canopy depends not only on solar radiation but also on the composition of incident radiation.

Comparing the morphological characteristics of high and low yielding cultivars of rice, Tsunoda (1964) revealed the close correlation between the erectness of leaves and yield. He concluded that the high crop yield is generally observed for rice cultivars with erect leaves. The research results obtained in a series of his investigation led him to the "plant type concept" as a guide for breeding high yielding cultivars.

Theory and experimental evidence showed that the plant architecture leads to the maximisation of incident solar radiation (Duncan, 1971). A combination of short, erect upper leaves grading to droopy, longer lower leaves is ideal for maximum crop photosynthesis.

Shibles and Weber (1965) observed that percent net radiation interception and rate of drymatter production increased with increase in leaf area. The net radiation above vegetative surfaces ranges between 50 to 70 percent of total short wave radiation depending mainly on the development of the plant canopy.

The canopy structure is specified by vertical distribution function of leaf area density and the orientation function i.e. the inclination and azimuth angles. Ross and Nilson (1966) studied the geometry of leaf orientation function within crop canopies and found that rice is more near vertical than erectophile. Canopy structure has been analysed more accurately in rice crops and it is revealed that the canopy structure of rice changes from a nearly ideal type before the heading stage to a quite inverse structure after the heading stage (Ito, 1969). Hayashi (1969) found that many high yielding varieties are short, erect leaved and high tillering.

Yoshida _et_ _al_. (1972) have discussed the physical meaning of erect leaves in terms of light use by a plant community. Hayashi (1972) has made comprehensive studies of the canopy structure of rice cultivars in relation to the search for a plant type maximising photosynthetic energy utilisation. He showed that the value of the extinction coefficient varies some-what among rice varieties, depending on the leaf arrangement in rice canopy. The more erectophile varieties developed larger leaf area indices and produced more drymatter at a given leaf area.

The radiation penetration within the crop canopy to a larger extent depends on the extinction coefficient of the crop (Monteith, 1972). Udagawa et al. (1974) calculated an extinction coefficient between .6 and .7 for a rice canopy.

Sciecz (1974) found that the net short wave radiation rapidly diminishes with increase in the depth of the crop canopy. He stressed the importance of shape of canopy and inclination of leaves in relation to light utilisation and pointed out that the drymatter accumulation of plants may differ according to the habit of the assimilation system, even when there is no difference in leaf area or photosynthetic efficiency.

Kanda (1975) has recorded that about 3 to 5 percent of Photosynthetically Active Radiation is lost by reflection at the canopy surface.

b) Albedo (Reflection coefficient).

The albedo, defined as the percentage of incoming shortwave solar radiation that is reflected, was measured over the crop. The albedo of a vertical leaved canopy decreases drastically with sun altitude whereas that of the horizontal leaved canopy is retained at a constant value independently of sun altitude (Ross, 1962). For rice canopies it decreases rapidly with increase of solar radiation from 28 percent at $h_o = 15^o$ to 13 percent at $h_o = 70^o$.

Japanese researchers (Anon, 1967) found a reflection coefficient of .08 at the time of transplant and a value of .22 when the cover became dense.

Denmead (1969) observed the change in the reflection coefficient with solar elevation.

Hayashi (1972) reported that in the ripening period the albedo of a rice crop is somewhat lower. Kishida (1973) measured the albedo of rice canopy in the wave range of Photosynthetically Active Radiation and showed that the albedo for photosynthetically Active Radiation was lower than that for total shortwave radiation.

The seasonal variation in the values of albedo for a rice crop is approximately parallel to that of leaf area index. Isdu et al. (1977) established a linear relationship between albedo and leaf area index upto 95 days after sowing and also between albedo and grain yield.

2. Photosynthesis and yield of rice.

The photosynthesis during ripening contributes to grain carbohydrate by 60 - 100 percent under usual conditions. Grain carbohydrate depends more on accumulated carbohydrate when light intensity after heading is low because photosynthesis during ripening is reduced (Soga and Nozaki,1957).

Takeda and Kumara (1957) compared the photosynthetic rate per rice **plant** in fields'P' and with that of isolated plants 'P_O'. P_O is larger than P, and the difference between them increased with increasing leaf area. They ascribed this to the mutual shading of leaves, and called the ratio P/P_O the light receiving coefficient.

The results of Watson and Witis (1959) suggest that the leaf arrangement and leaf angle exert a large influence on the net assimilation rate when mutual shadding of leaves occur.

The sunlit leaf area plays a very important role in canopy photosynthesis. Warren Wilson (1963) found the sunlit area index of rice crop with very erect leaves to be about '2'.

Tanaka et al. (1964) reported lower drymatter accumulation and decreased photosynthesis under shaded conditions. Stansel et al. (1965) stated that under low light intensity conditions sterility increased, taller plants were produced and yields were reduced.

According to Murata (1966) the accumulation of starch in the leaves and culms begins about 10 days before heading. Starch accumulates markedly in the grain during the 30 days period following heading. The total period of 40 days before heading may be considered as the period of grain production (Murata, 1966; Yoshida and Ahn, 1968).

The influence of leaf inclination angle on canopy photosynthesis has been reported with regard to rice by Tanaka (1972). The yield of the horizontal leaved rice canopy was about 70 percent that of the vertical leaved canopy.

Mathematical models for the evaluation of canopy photosynthetic activity of leaf, leaf amount and of radiation energy distribution in the canopy have also been developed.

3. Effect of row orientation.

Very few investigations on the effect of row orientation on yield have been made so far. These few studies, however, bring out results that are surprisingly similar with different crop growth under widely differing conditions.

In the USSR, spring wheat sown in North-South orientation produced 100-300 kg/ha more than when sown in East - West (Perekaljskii ,1951).

Dungan et al. (1955) found that maize planted in a North-South direction yielded significantly more grain and forage than when it was planted in an East-West direction. They also reported that the yield of maize fodder sown in the North-South lines was more than that sown in East-West orientation though the difference was not significant.

Pendleton and Dungan (1958) in Illinois stated that oats drilled in North-South direction yielded significantly more grain than that seeded in East-West direction, the advantage of the North-South row increased as interrow spacing increased. Further, they reported that the interception of solar radiation by differently oriented crop is dependent on season and latitude.

In Australia, 6.5 percent and 11 percent yield increase in drymatter production in wheat, were obtained in two experiments with North-South sowing as compared to East-West sowing (Santhirasegaram, 1962).

According to Yao and Shaw (1964) the different row directions with different spacing show variable radiation interception. Because of sunlight intercepted by the rice crop, plant spacing and row orientation also affect the grain yield of rice (Matsuo, 1964).

Sandhu (1964) reported that pearlmillet sown in North-South oriented rows produced taller plants and more grain yield compared to that sown in East-West direction giving higher grain, straw and protein yields.

Light penetration was predicted for East-West, North-South, North East-South West and North West-South East row orientations using row geometry of East-West wide row grain sorghum at Colorado (Allen, 1974). The model predicted 37, 44, 42 and 42 percent daily interception respectively. The North East-South West row orientation might be best since the model predicted that the most light would be absorbed at 10.00 hr., and when moisture stress would be low, and the least at 14.00 hr., when the moisture stress would be high.

Linvill and Dale (1975) observed that both the plant density and geometry could affect net radiation of corn plants but the difference in net radiation would be small.

Pigarera and Rusanenko (1977) concluded that the effect of solar radiation were stronger on grain quality of wheat grown in North-South rows than grown in East-West row orientation in Saratov province of USSR.

Dhillon and Kler (1981) concluded that sowing wheat in North-South direction resulted in significant increase in yield over the crop sown in East-West direction probably due to better penetration of light, thus illuminating more number of lower leaves.

Murthi (1982) recorded highest grain yield in wheat planted in North-South orientation.

4. Effect of spacing on the growth and yield of rice.

Hidayatullah and Sen (1944) reported that productive tillers and panicle length were functions of spacing. Murata *et al*. (1957) found that the narrower the spacing the greater the photosynthetic ability at the early to middle stage of growth. However, the relationship was reversed in the later stages.

The grain weight per unit area increases with a decrease in spacing upto a certain extent, after which there is no change or decrease, depending on the character of the variety (Kanda and Kakizaki, 1957). Under a fully fertilised condition, the total yield of the drymatter per unit area at harvest time became constant regardless of its density. Thus was observed the "law of constant final yield in plant growth" (Kira, 1959).

The effect of plant density on the yield of rice for traditional varieties (Vacchani and Rao, 1959; Yin et al. 1960; Matsuo, 1964) and modern varieties (Fagade and De Datta, 1971) has been studied. The short, lodging-resistant, photoperiod-insensitive varieties such as IR-8, IR-36 etc. should be spaced 20cm X 25 cm in the wet season regardess of soil fertility.

Vacchani et al. (1961) have recorded increased plant height in increased spacing. He obtained significantly higher yield under a close spacing of 15 cm X 15 cm at CRRI, Cuttack.

Number of panicles, total number of spikelets per unit area increased and the weight per panicle and mean grain weight decreased with increase in plant density (Yamada, 1961; Anon, 1964; Tanaka et al. 1964).

Trials conducted at CRRI, Cuttack for four seasons with high yielding varieties indicated that spacing effect or interactions with other factors were not significant in the majority of seasons, with the result that specific plant population requirements could not be conclusively defined (Rao, 1966).

Lei and Xi (1967) obtained greater plant height in closer spacing.

Bhan (1967) reported very little difference in the nutrient content of plant tissue as influenced by spacing and population, but drymatter production increased with increase in spacing.

Bains and Singh (1967) observed a spacing of 15 cm X 15 cm and two seedlings per hill as the optimum combination to realise higher yields under low hill conditions in U.P. Kulandaivelu (1967) reported that a spacing of 20 cm X 10 cm increased the yield components of each plant, but did not increase overall yield of grain due to reduction in plant population per unit area.

Results of the experiments conducted under the AICRIP during Rabi 1968 showed a spacing of 20 cm X 15 cm to be good for IR - 8 (Anon, 1968).

Asbertin and Peters (1961) found that plant population and row width affect the relative amount of energy absorbed by the plants and the soil. They found slightly higher fractions of net radiation near the ground, and reported them to vary with plant density in corn. Yao and Shaw (1964) reported that the ratio of net radiation at the ground to that above the canopy in a fixed plant population showed a decrease with decrease in spacing, the closer the spacing the lower was the value.

Increase in the number of grains per panicle and number of spikelets per panicle with wider spacing were also reported (Anon, 1964; Matsuo, 1965; Ahmed and Rao, 1966).

Studies on a medium tillering, nitrogen responsive ponlai variety revealed that the modern rice plant can be transplanted at any distance from 10 - 35 cm without significant difference in yield (Anon,1965). Chandler (1965) suggested that the short, erect leaved, heavy tillering varieties developed in South East Asia can be transplanted at distances ranging from 10 cm X 10 cm to 30 cm X 30 cm without any significant change in yield provided other cultural practices are ideal.

The tiller number per unit area in a rice population is largely a function of plant density. The tiller number is positively or negatively correlated with grain yield depending on the rice variety and crop environment (Kawano and Tanaka, 1968). According to Mandal and Mahapatra (1968) number of effective tillers were obtained under closer spacing.

Allen (1974) suggested that row spacing and crop cover influence the net radiation partition to a greater extent.

Closer spacing proved to be more favourable for rice production to the sunny and hot second crop season. During the second crop season 20 cm X 10 cm spacing was found to be the best for PTB - 20 and RP4 - 14 (Anon, 1975).

In an experiment conducted at IARI highest yield was obtained when row and plant spacing were kept minimum at 7.5 cm X 7.5 cm (Parashar, 1976).

Lerch (1976) has found that increase in plant population decreased the number of tillers and panicles, leaf area and yield per plant but increased the total area, drymatter production and paddy yield per square meter and concluded that closely spaced plants utilise more solar radiation for grain production more effectively than those with widely spaced.

Effect of plant spacing and number of seedlings per hill on growth and yield of rice variety 'Jaya' was studied at PAU during 1973 - '74 (Shahi and Gill, 1976). No significant deflection in grain yield was observed.

Singh and Modjal (1977) observed that plant spacing did not influence grain yield. Though there was an increase in panicle number with reduced spacing the favourable effects might have been offset by decreased number of spikelets per panicle.

Venketeswarlu and Sreenivasan (1978) have reported that the yield losses due to the shading effect could be compensated to some extent by increasing population density.

Nguu and De Datta (1979) reported the effect of plant density on grain yield of rice grown with various levels of soil nitrogen. The rate of fertiliser application affected the yield response to plant density.

Devi et al. (1981) concluded that closer spacing would be required for the second crop season while a wider spacing of 20 cm X 15 cm would be suitable for the first crop season.

Field experiments conducted in dry and wet seasons showed that the drymatter of rice accumulated per unit area was slightly high (5 percent) in plots having one skip row after every two rows planted 20 cm apart (Goutam, et al. 1984). The rows bordering the skip row produced more filled grains than the control plants, compensating for the missing rows under the skip row planting.

MATERIALS AND METHODS

MATERIALS AND METHODS

A field experiment designed to study the influence of crop geometry on the growth and yield of rice variety 'Jaya' was conducted during the second crop season of 1983 at the Regional Agricultural Research Station, Pattambi. The field selected for the experiment was under bulk crop of paddy for the previous two seasons.

1. Materials.

1.1. Site, climate and soil.

The research station is situated at 10° 48' N Latitude and 76° 12' E Longitude at an altitude of 25.36 m above MSL. This area enjoys a typical humid tropical climate.

The details of the meteorological observations for the period are presented in Table 1.1.1. and Figure 1.

The soil of the experimental area is sandy loam in texture.

The chemical properties of the soil are given below:

Organic carbon	1.315%
Total nitrogen	.222%
Total P_2O_5	.0168%
Total K_2O	.0136%
Available P_2O_5	16.11ppm
Available K_2O	115.07 ppm
pH	5.4

Table 1.1.1

Mean weekly weather parameters for the crop growth period.

Duration Period	Temperature (°C)		Relative Humidity (%)	Total Rainfall (mm)	Sunshine (hours)	Wind Velocity (Km/hr)	Pan evaporation (mm)
	Max.	Min.					
1.10.'83 to 7.10.'83	29.8	23.7	88.7	53.4	5.4	3.0	14.2
8.10.'83 to 14.10.'83	31.2	22.0	80.0	Nil	9.2	2.3	33.4
15.10.'83 to 21.10.'83	31.5	23.0	81.5	25.2	6.9	2.1	12.0
22.10.'83 to 28.10.'83	32.5	23.5	80.4	83.2	6.1	1.6	12.7
29.10.'83 to 4.11.'83	32.3	23.4	81.2	61.4	6.0	1.8	13.7
5.11.'83 to 11.11.'83	32.3	21.8	74.9	1.5	9.0	1.5	26.9
12.11.'83 to 18.11.'83	33.1	20.0	67.5	Nil	10.2	1.6	26.0
19.11.'83 to 25.11.'83	32.1	21.7	79.5	31.7	7.5	0.9	20.5
26.11.'83 to 2.12.'83	32.4	21.9	69.0	Nil	8.7	3.3	27.3
3.12.'83 to 9.12.'83	32.7	23.0	65.5	4.0	8.2	5.2	33.4
10.12.'83 to 16.12.'83	34.0	23.0	65.0	Nil	9.6	4.4	38.3
17.12.'83 to 23.12.'83	31.7	23.3	72.5	1	9.0	4.9	30.2
24.12.'83 to 31.12.'83	31.8	22.9	77.5	38.5	7.1	2.7	11.9
1. 1.'84 to 7.1 . '84	33.0	22.9	61.0	Nil	8.8	5.1	38.7
8. 1.'84 to 14. 1.'84	32.2	23.0	58.5	Nil	6.8	5.3	37.7
15.1. '84 to 21.1.'84	33.7	22.0	70.5	14	7	2.9	23.6
22.1. '84 to 28.1.'84	33.7	19.5	64.5	Nil	9.8	3.6	40.6
29.1.'84 to 4.2.'84	34.1	22.7	56.5	Nil	8.2	5	38.3
5.2.'84 to 11.2.'84	34.3	24.5	64.0	Nil	5.5	5.8	42.8

1.2. Season.

The experiment was conducted during the period from October, 1983 to February, 1984.

1.3. Variety.

The variety 'Jaya' selected for the study is one of the early semi dwarf varieties developed in India which created a significant impact on rice production in the country. It is a photoinsensitive variety developed from the cross between TN - 1 and T 141. The duration of the variety is 130 days.

1.4. Manures and fertilisers.

Farmyard manure at the rate of 5000 kg per hectare was applied uniformly as basal dressing. In addition, lime (54 percent CaO) was applied uniformly at the rate of 600 kg per hectare about 4 days prior to planting. Urea, Super phosphate and Muriate of potash were used as fertilisers to supply the required quantity of nitrogen (at the rate of 90 kg N per hectare), phosphate (at the rate of 45 kg P_2O_5 per hectare) and potassium (at the rate of 45 kg K_2O per hectare) respectively.

2. Methods.

2.1. Layout.

The experiment was laid out in split plot design with three replications. The layout plan is given in Figure 2. The treatments consisted of combination of two levels of spacing between plants and three levels of spacing between alleys in the mainplot and four levels of crop orientation in the subplot. The different treatments given in the experiment are denoted by the symbols:-

1. Spacing between plants.

   S_1 - 20 cm X 15 cm
   S_2 - 20 cm X 10 cm

2. Spacing between alleys (40 cm wide)

   A_1 - 80 cm apart (Alleys are taken after every 4 rows of paddy).

   A_2 - 160 cm apart (Alleys are taken after every 8 rows of paddy).

   A_3 - 240 cm apart (Alleys are taken after every 12 rows of paddy).

3. Crop orientation.

   O_1 - North - South

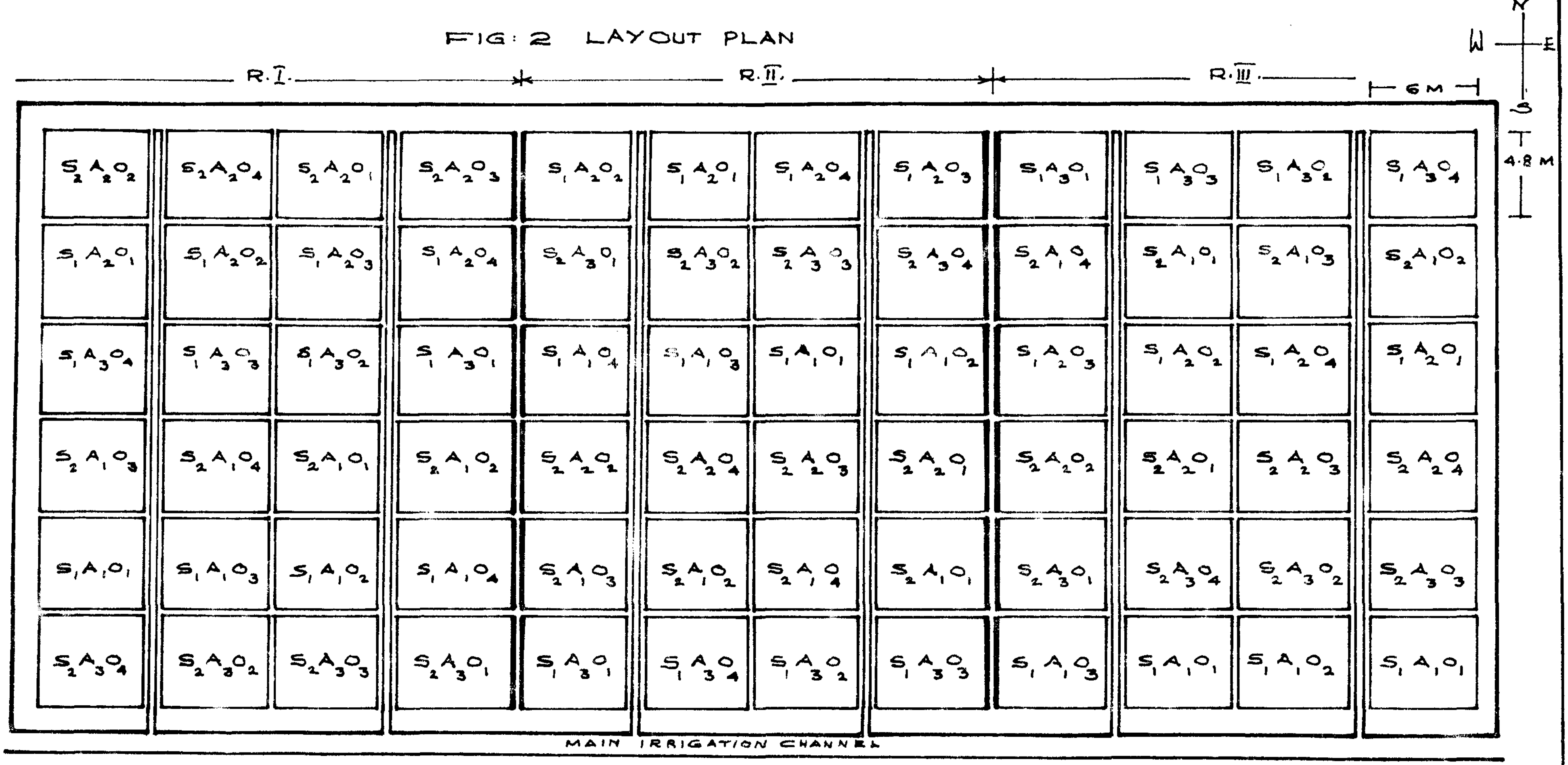
   O_2 - East - West

   O_3 - Diagonal planting (North East - South West)

   O_4 - Diagonal planting (North West - South East)

   Net plot size - 6 m X 4.8 m.

FIG: 2 LAYOUT PLAN



$S_2A_2O_2$	$S_2A_2O_4$	$S_2A_2O_1$	$S_2A_2O_3$	$S_1A_2O_2$	$S_1A_2O_1$	$S_1A_2O_4$	$S_1A_2O_3$	$S_1A_3O_1$	$S_1A_3O_3$	$S_1A_3O_2$	$S_1A_3O_4$
$S_1A_2O_1$	$S_1A_2O_2$	$S_1A_2O_3$	$S_1A_2O_4$	$S_2A_3O_1$	$S_2A_3O_2$	$S_2A_3O_3$	$S_2A_3O_4$	$S_2A_1O_4$	$S_2A_1O_1$	$S_2A_1O_3$	$S_2A_1O_2$
$S_1A_3O_4$	$S_1A_3O_3$	$S_1A_3O_2$	$S_1A_3O_1$	$S_1A_1O_4$	$S_1A_1O_3$	$S_1A_1O_1$	$S_1A_1O_2$	$S_1A_2O_3$	$S_1A_2O_2$	$S_1A_2O_4$	$S_1A_2O_1$
$S_2A_1O_3$	$S_2A_1O_4$	$S_2A_1O_1$	$S_2A_1O_2$	$S_2A_2O_2$	$S_2A_2O_4$	$S_2A_2O_3$	$S_2A_2O_1$	$S_2A_2O_2$	$S_2A_2O_1$	$S_2A_2O_3$	$S_2A_2O_4$
$S_1A_1O_1$	$S_1A_1O_3$	$S_1A_1O_2$	$S_1A_1O_4$	$S_2A_1O_3$	$S_2A_1O_2$	$S_2A_1O_4$	$S_2A_1O_1$	$S_2A_3O_1$	$S_2A_3O_4$	$S_2A_3O_2$	$S_2A_3O_3$
$S_2A_3O_4$	$S_2A_3O_2$	$S_2A_3O_3$	$S_2A_3O_1$	$S_1A_3O_1$	$S_1A_3O_4$	$S_1A_3O_2$	$S_1A_3O_3$	$S_1A_1O_3$	$S_1A_1O_1$	$S_1A_1O_2$	$S_1A_1O_1$

TREATMENTS - 24
REPLICATIONS - 3
DESIGN - RBD
PLOT SIZE - 6 M x 4.8M

SPACING BETWEEN PLANTS
S_1 - 20 cm x 15 cm
S_2 - 20 cm x 10 cm

TREATMENTS

SPACING BETWEEN ALLEYS (40 cm WIDE)
A_1 - 80 cm APART (ALLEYS ARE TAKEN AFTER EVERY 4 ROWS OF PADDY)
A2 - 120 cm APART (ALLEYS ARE TAKEN AFTER EVERY 8 ROWS OF PADDY)
A3 - 240 cm APART (ALLEYS ARE TAKEN AFTER EVERY 12 ROWS OF PADDY)

CROP ORIENTATION - O_1 - NORTH - SOUTH
O_2 - EAST - WEST
O3 - DIAGONAL PLANTING (NORTH EAST - SOUTH WEST)
O4 - DIAGONAL PLANTING (NORTH WEST - SOUTH EAST)

2.2. Cultural Operations.

The cultivation practices recommended for 'Jaya' by the Kerala Agricultural University were followed.

The land was ploughed twice and the soil was brought to a puddled condition. Farmyard manure was uniformly spread all over the field before the second ploughing. Lime was applied at the rate of 600 kg per hectare in two split doses; the first dose at 350 kg per hectare as basal dressing at the time of final ploughing and the second dose at 250 kg per hectare as top dressing about one month after planting.

A uniform dose of 45 kg nitrogen, 45 kg P_2O_5 and 22½ kg K_2O per hectare applied in all plots before last puddling. Remaining 45 kg of nitrogen and 22½ kg of K_2O per hectare were topdressed 5 to 7 days prior to the panicle initiation stage.

The seeds were sown on 1st October, 1983. The seed rate used was 80 kg per hectare. Twenty five days old seedlings were transplanted with two seedings per hill. Controlled irrigation and drainage were done as and when required. The plots were handweeded twice 30 days and

45 days after transplanting. Two protective sprayings with Ekalux on 20th day after planting and Leybacid and Hinosan on 50th day after planting were given.

The stand of the crop in general was good throughout the period of growth. The crop was harvested on February 7th, 1984.

2.3. Observations.

2.3.1. Crop growth characters and yield components.

a) Height of plants.

The plant height in cm was recorded on the 30th and 60th day after planting and at harvest. Height of plants was measured from the bottom of the culm to the tip of the largest leaf or tip of the earhead whichever was tallest.

b) Number of tillers.

Number of tillers per sq.m. was counted on the above dates.

c) Leaf area index.

Leaf area index was recorded on 40th, 75th and 90th day after planting and at harvest.

d) Number of productive tillers.

Number of productive tillers per sq.m. was counted.

e) Length of panicle.

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

f) Number of grains per panicle.

Number of grains in each panicle was recorded.

g) Thousand grain weight.

One thousand grains were counted, weighed and the weight was recorded in gm.

h) Grain yield.

The grain harvested from each plot was cleaned, dried and weighed. From this yield in Kilograms per hectare was calculated and recorded.

i) Straw yield.

The weight of sun dried straw was recorded plotwise and from this the yield of straw in Kilograms per hectare was computed.

j) Drymatter production.

Total drymatter production in Kilograms per hectare was worked out.

K) Grain - straw ratio.

Grain - straw ratio was also worked out.

2.3.2. Meteorological observations.

The daily values of meteorological parameters (maximum and minimum temperatures, rainfall, humidity, sunshine hours, wind velocity, evaporation etc.) recorded at the meteorological observatory adjacent to the experimental site were used.

Albedo

The incoming and reflected radiations in the crop canopy were measured using an Albedometer CN 8 (Medos Company Pty Ltd, Middleton Instruments, Australia). The instrument has the temperature compensated sensor and double glass hemispheres. The shield which protects the body from incident radiation, is specially designed so that the area of the shadow cast is minimised. The instrument head carries a spirit level and a desiccant tube is fitted in the handle.

The instrument was held at a height of 1 m above the rice crop. The incoming and reflected radiations were measured by keeping the sensor in up-facing and down-facing positions. The data were recorded at 5 minutes interval. The measurements were made on clear days.

Determination of albedo was made from the formula:

$$\text{Albedo} = \frac{\text{Voltage output of down-facing sensor}}{\text{Voltage output of up-facing sensor}} \times 100.$$

The incoming solar radiation (Rs) was also worked out using the formula $Rs = (.29 + .42\ n/N)\ Ra$ where **Ra** is the mean equivalent evaporation in mm per day and n/N being the ratio between actual measured bright sunshine hours and maximum possible sunshine hours. The values of N (hours) and Ra (mm/day) for the particular latitude (10° 48' N) are taken from the tables given the "Crop Water Requirement", FAO, 1977. Using these values of incoming radiation and the recorded albedo values the amount of reflected radiation was also worked out.

2.4. Chemical analysis.

The N, P, K contents of rice plants at harvest were determined.

The nutrient uptake per hectare was also calculated.

2.5. Statistical analysis.

The data recorded for plant growth characters, yield and yield attributes, nutrient contents of plant etc. were subjected to statistical analysis by applying the analysis of variance technique for split plot design as suggested by Panse and Sukhatme (1954).

RESULTS

RESULTS

The results of the experiment conducted to study the influence of crop geometry on the growth and yield of rice variety 'Jaya' are furnished below:

1. Plant height.

The observations on height of plants taken on 30th and 60th day after planting and at harvest were taken and analysed separately and the analysis of variance tables are presented in Appendices I, II and III respectively. The mean heights are presented in Tables 1, 2 and 3.

On the 30th day the effect due to orientation was found to be highly significant. From Table 1 it is seen that among the different crop orientations, the plant height of N-S oriented crop was the maximum (56.4 cm). The E-W oriented crop recorded the lowest value (53.4 cm). The mean height of the NW-SE and NE-SW oriented plants were on par.

Among the various interactions, that of S_2 spacing X A_1 alley was found to be highly significant. The maximum height for this combination was 56.2 cm. The least value of plant height (53.2 cm) was in the S_1 X A_1.

Table 1

Height of plant on 30th day after planting (cm).

	O_1	O_2	O_3	O_4	Mean
S_1	55.28	53.10	54.11	55.71	54.55
S_2	57.52	53.70	54.44	54.41	55.02
A_1	57.98	53.52	52.85	54.40	54.69
A_2	55.40	53.27	54.75	55.27	54.67
A_3	55.82	53.42	55.23	55.52	55.00
S_1A_1	55.40	52.60	51.10	53.70	53.20
S_1A_2	54.50	53.30	55.60	55.70	54.92
S_1A_3	56.00	53.40	55.70	57.10	55.55
S_2A_1	60.60	54.40	54.60	55.10	56.18
S_2A_2	56.30	53.20	53.90	54.30	54.43
S_2A_3	55.70	53.40	54.80	53.90	54.45
Mean	56.40	53.40	54.28	55.06	---

Spacing : SE_m = ± .93

Alleys : SE_m = ± .93

Orientation: SE_m =±1.48 C.D (.05)=1.73 $\overline{O_1\;\underline{O_4}}\;\;\overline{\underline{O_3}\;O_2}$

Table 1 (a)

Combined effect of Spacing between plants and spacing between alleys on height of plant on 30th day after planting (cm).

	A_1	A_2	A_3	Mean
S_1	53.20	54.90	55.60	54.55
S_2	56.20	54.40	54.40	55.02
Mean	54.69	54.67	55.00	---

SE_m =±.93 C.D (.05) =1.46 $\underline{S_2A_1\ \overline{S_1A_3\ S_1A_2}}\ \underline{\overline{S_2A_3\ S_2A_2}\ S_1A_1}$

Table 2

Height of plant on 60th day after planting (cm).

	O_1	O_2	O_3	O_4	Mean
S_1	69.50	65.30	68.20	68.80	68.00
S_2	67.90	64.90	66.20	66.10	66.30
A_1	68.98	65.42	67.57	67.02	67.25
A_2	68.93	65.03	66.88	68.23	67.27
A_3	68.12	64.88	67.15	67.08	66.81
S_1A_1	69.00	65.87	68.13	68.00	67.75
S_1A_2	68.73	64.43	68.00	69.57	67.68
S_1A_3	70.67	65.53	68.60	68.93	68.43
S_2A_1	68.97	64.97	67.00	66.03	66.74
S_2A_2	69.13	65.63	65.77	66.90	66.86
S_2A_3	65.57	64.23	65.70	65.23	65.18
Mean	68.70	65.10	67.20	67.50	---

Spacing: SE_m =±1.14 C.D (.05) = 1.8

Alleys : SE_m =±1.14

Orientation: SE_m =±2.14 C.D(.05)=2.49 $\overline{O_1 \; O_4 \; \underline{O_3}}\,\underline{\; O_2}$

Table 3

Height of plant at the time of harvest(cm).

	O_1	O_2	O_3	O_4	Mean
S_1	71.44	69.68	70.21	69.78	70.28
S_2	70.87	66.50	68.13	68.20	68.43
A_1	71.90	68.20	69.75	69.02	69.72
A_2	71.80	69.98	70.32	70.30	70.60
A_3	69.77	66.08	67.45	67.65	67.74
S_1A_1	72.10	69.50	70.93	69.50	70.71
S_1A_2	72.23	70.93	70.00	70.20	70.84
S_1A_3	70.00	68.60	69.70	69.63	69.48
S_2A_1	71.70	66.90	68.57	68.53	68.93
S_2A_2	71.37	69.03	70.63	70.40	70.36
S_2A_3	69.53	63.57	65.20	65.67	65.99
Mean	71.16	68.09	69.17	68.99	---

Spacing: SE_m = ±.81 C.D (.05) = 1.28

Alleys : SE_m = ±.81 C.D (.05) = 1.28 $\overline{A_2 \quad A_1}$ A_3

Orientation: SE_m = ±2.74

Table 3 (a)

Combined effect of spacing between plants and spacing between alleys on height of plant at the time of harvest (cm).

	A_1	A_2	A_3	Mean
S_1	70.50	70.80	69.50	70.30
S_2	68.90	70.40	66.00	68.40
Mean	69.70	70.60	67.80	---

SE_m = .81 C.D(.05)=2.74 $\overline{S_1A_2\ S_1A_1\ S_2A_2\ S_1A_3\ S_2A_1}$ S_2A_3

From Table 2, it is seen that on the 60th day the effect of various orientations on height was significant. The N-S orientation showed the maximum height (68.7 cm). E-W oriented crop had the lowest value(65.1 cm).

The data also reveal that the difference in height of plants due to spacing was highly significant, the maximum being 68.0 cm in S_1 spacing (20 cm X 15 cm). The difference in the interactions was not found to be significant.

The data in Table 3, show that at the time of harvest the effect due to spacing between plants on height was highly significant. The maximum height (70.3 cm) was observed in the S_1 spacing (20 cm X 15 cm).

The effect due to different spacings between alleys was significant. The A_2 (ie; 160 cm apart) recorded the maximum height (70.6 cm) followed by A_1 and A_3 respectively.

Regarding treatment combinations, S_1 spacing (20 cm X 15 cm) with A_2 alley (160 cm apart) showed the maximum height (70.8 cm). The lowest value (66.0 cm) was observed in S_2 X A_3 combination.

2. Number of tillers.

The analysis of variance tables corresponding to the observations on number of tillers on 30th and 60th day after planting and at harvest are given in Appendices IV, V and VI respectively. The mean number of tillers per sq.m. at each observation is presented in Tables 4, 5 and 6.

The data show that on the 30th day the difference in the number of tillers due to orientation is highly significant and also due to spacing. The N-S oriented crop recorded the maximum bumber of tillers (482). NE-SW orientation showed the least value (404).

The interaction effects were not significant.

From Table 5, it is seen that on the 60th day the effect due to orientation was highly significant. The number of tillers produced in N-S orientation was significantly higher (577). E-W and NW-SE orientations were on per and the NE-SW orientation showed the lowest value (449). As compared to E-W and NW-SE orientations, the N-S oriented crop produced 17.7% more number of tillers.

The table also shows that the difference in the number of tillers due to spacing is also highly significant. The value of S_1 is the highest (553) while that of S_2 is 453.

Table 4

Number of tillers per square meter on 30th day after planting.

	O_1	O_2	O_3	O_4	Mean
S_1	520	478	442	463	475
S_2	443	451	365	425	421
A_1	523	479	420	440	443
A_2	464	454	389	444	438
A_3	459	460	402	447	440
S_1A_1	540	490	450	475	489
S_1A_2	505	495	435	480	479
S_1A_3	515	495	440	425	469
S_2A_1	505	470	390	405	443
S_2A_2	425	415	340	410	398
S_2A_3	400	470	365	460	424
Mean	482	465	404	444	--

Spacing: SE_m = ± 33.0 C.D(.05) = 60.17

Alleys : SE_m = ± 33.0 C.D(.05) = 60.17

Orientation: SE_m = ± 26.5 C.D(.05) = 31.13 $\overline{O_1\ \underline{O_2}}\underline{\ O_4}\ O_3$

Table 5

Number of tillers per square meter on 60th day after planting.

	O_1	O_2	O_3	O_4	Mean
S_1	676	525	474	537	553
S_2	478	462	424	449	453
A_1	621	507	457	463	512
A_2	586	514	474	531	526
A_3	524	460	417	484	471
S_1A_1	705	514	479	507	551
S_1A_2	679	582	549	559	592
S_1A_3	644	479	395	545	516
S_2A_1	537	500	435	419	473
S_2A_2	494	445	399	504	461
S_2A_3	403	442	439	424	427
Mean	577	494	449	493	--

Spacing: $SE_m = \pm 16.0$ C.D(.05) = 25.5

Alleys : $SE_m = \pm 16.0$ C.D(.05) = 25.5 $\overline{A_2 \quad A_1} \quad A_3$

Orientation: $SE_m = \pm 32.0$ C.D(.05) = 37.0 $O_1 \quad \overline{O_2 \quad O_4} \quad O_3$

Table 5 (a)

Combined effect of spacing between plants and spacing between alleys on number of tillers per square meter on 60th day after planting.

	A_1	A_2	A_3	Mean
S_1	551	592	516	553
S_2	473	461	427	453
Mean	512	526	471	--

SE_m = ± 16.0 C.D (.05) = 25.5

S_1A_2 S_1A_1 S_1A_3 $\overline{S_2A_1 \quad S_2A_2}$ S_2A_3

Table 6

Number of tillers per square meter at the time of harvest.

	O_1	O_2	O_3	O_4	Mean
S_1	486	460	437	450	548
S_2	447	415	362	385	402
A_1	449	436	408	431	431
A_2	461	437	404	424	432
A_3	489	439	389	398	429
S_1A_1	487	437	445	442	453
S_1A_2	404	465	432	490	448
S_1A_3	507	489	435	419	463
S_2A_1	459	419	370	420	417
S_2A_2	459	419	375	359	403
S_2A_3	472	390	342	377	395
Mean	467	438	400	418	---

Spacing: $SE_m = \pm 14.5$ C.D(.05) = 23

Alleys : $SE_m = \pm 14.5$

Orientation: $SE_m = \pm 26.5$ C.D(.05)=31 $\overline{O_1}\ \underline{O_2\ \overline{O_4}}\ O_3$

It is also seen that the difference due to alleys too, is highly significant. The highest value (526) is seen due to A_2 alleys.

The interaction effect of S X O and S X A showed significant differences. The maximum effect is perceived in S_1 X O_1 (676).

Among the S X A combinations the highest value (592) was for S_1A_2.

From Table 6, it is seen that at the time of harvest the effects due to various orientations and due to spacing were highly significant.

The data indicate that N-S oriented crop produced significantly more number of tillers (467). The least value was observed in the NE-SW oriented crop (400).

The S_1 spacing produced the maximum number of tillers (458) and the S_2 had a value of 402.

However, the interaction effects were not significant.

A considerable reduction in the total number of tillers was also noticed during the period from 60th day after transplanting to the time of harvest.

3. Leaf area index.

The analysis of variance tables for the leaf area index at different stages as stated before are presented in Appendices VII, VIII, IX and X and the mean values in Tables 7, 8, 9 and 10 respectively.

Appendix VII shows that the variation in leaf area index due to orientation is highly significant. From the Table 7 it is seen that on the 40th day after planting the leaf area index in N-S orientation was highest (7.4). E-W orientation recorded the least value (4.1).

It is also seen that the effect of spacing is also highly significant. Spacing S_2 recorded the maximum leaf area index (6.2).

The effect of alleys is found to be significant. The maximum value of leaf area index turned out to be 6.3 for A_2.

Among the interactions only S X A and S X A X O were significant. S_2 X A_2 showed the highest value(6.5) among the S X A combinations. Regarding S X A X O combinations S_2 X A_2 X O_1 recorded the highest value (8.2).

On the 75th day after planting the orientation effect was found to be highly significant. N-S oriented

Table 7

Leaf area index on 40th day after planting

	O_1	O_2	O_3	O_4	Mean
S_1	6.94	3.69	5.66	5.60	5.47
S_2	7.92	4.41	6.26	6.25	6.21
A_1	7.05	3.90	5.57	5.64	5.54
A_2	7.82	4.26	6.57	6.53	6.30
A_3	7.41	3.99	5.74	5.60	5.69
S_1A_1	6.20	3.64	4.82	4.83	4.87
S_1A_2	7.45	3.84	6.42	6.51	6.06
S_1A_3	7.16	3.59	5.74	5.46	5.49
S_2A_1	7.90	4.16	6.32	6.45	6.21
S_2A_2	8.19	4.68	6.72	6.56	6.54
S_2A_3	7.66	4.39	5.74	5.74	5.68
Mean	7.43	4.05	5.96	5.93	---

Spacing: $SE_m = \pm .08$ C.D (.05) = .13

Alleys : $SE_m = \pm .08$ C.D (.05) = .13 A_2 A_3 A_1

Orientation: $SE_m = \pm .05$ C.D(.05)=.06 O_1 $\overline{O_3 \quad O_4}$ O_2

Table 7 (a)

Combined effect of spacing between plants and spacing between alleys on leaf area index on 40th day after planting.

	A_1	A_2	A_3	Mean
S_1	4.87	6.05	5.49	5.47
S_2	6.20	6.54	5.88	6.21
Mean	5.54	6.30	5.69	---

SE_m = ±.08 C.D(.05)=.13 S_2A_2 S_2A_1 S_1A_2 S_2A_3 S_1A_3 S_1A_1

Table 8

Leaf area index on 75th day after planting

	O_1	O_2	O_3	O_4	Mean
S_1	7.14	3.70	5.68	5.63	5.54
S_2	7.95	5.46	6.39	6.32	6.28
A_1	7.22	4.00	5.68	5.72	5.66
A_2	7.89	4.21	6.62	6.55	6.32
A_3	7.53	4.03	5.80	5.66	5.78
S_1A_1	6.53	3.71	4.80	4.84	4.97
S_1A_2	7.63	3.77	6.46	6.55	6.10
S_1A_3	7.27	3.62	5.78	5.48	5.54
S_2A_1	7.91	4.28	6.56	6.59	6.34
S_2A_2	8.15	4.67	6.78	6.55	6.54
S_2A_3	7.79	4.44	5.82	5.83	5.97
Mean	7.55	4.08	6.04	5.97	---

Spacing: SE_m = ±.04 C.D (.05) = .06

Alleys : SE_m = ±.04 C.D (.05) = .06 A_2 A_3 A_1

Orientation: SE_m = ±.03 C.D (.05)=.04 O_1 O_3 O_4 O_2

Table 8 (a)

Combined effect of spacing between plants and spacing between alleys on leaf area index on 75th day after planting.

	A_1	A_2	A_3	Mean
S_1	4.97	6.1	5.54	5.54
S_2	6.33	6.53	5.97	6.28
Mean	5.66	6.32	5.78	---

SE_m = ± .04 C.D(.05)=.06 S_2A_2 S_2A_1 S_1A_2 S_2A_3 S_1A_3

Table 9

Leaf area index on 90th day after planting.

	O_1	O_2	O_3	O_4	Mean
S_1	5.11	2.74	3.92	4.10	3.97
S_2	6.34	3.29	4.85	4.85	4.83
A_1	5.28	3.00	4.18	4.30	4.19
A_2	6.11	3.02	4.57	4.62	4.58
A_3	5.79	3.03	4.41	4.50	4.43
S_1A_1	4.44	2.49	3.62	3.80	3.59
S_1A_2	5.71	2.91	4.19	4.36	4.29
S_1A_3	5.18	2.83	3.95	4.13	4.02
S_2A_1	6.12	3.52	4.73	4.79	4.79
S_2A_2	6.51	3.14	4.94	4.88	4.87
S_2A_3	6.40	3.23	4.87	4.87	4.84
Mean	5.73	3.02	4.39	4.39	--

Spacing: $SE_m = \pm .02$ C.D.(.05) = .03

Alleys : $SE_m = \pm .02$ C.D (.05) = .03 A_2 A_3 A_1

Orientation: $SE_m = \pm .02$ C.D (.05) =.03 O_1 O_4 O_3 O_2

Table 9 (a)

Combined effect of spacing between plants and spacing between alleys on leaf area index on 90th day after planting.

	A_1	A_2	A_3	Mean
S_1	3.59	4.29	4.02	3.97
S_2	4.79	4.87	4.84	4.83
Mean	4.19	4.58	4.43	---

SE_m = ± .02 C.D(.05) =.03 $\overline{S_2A_2 \quad S_2A_3}$ S_2A_1 S_1A_2 S_1A_3 S_1A_1

Table 10

Leaf area index at the time of harvest.

	O_1	O_2	O_3	O_4	Mean
S_1	3.54	1.18	2.98	3.00	2.68
S_2	3.67	1.33	2.99	3.00	2.75
A_1	3.59	1.22	2.86	2.85	2.63
A_2	3.67	1.30	3.13	3.18	2.82
A_3	3.56	1.25	3.00	2.97	2.69
S_1A_1	3.49	1.11	2.83	2.86	2.57
S_1A_2	3.61	1.23	3.17	3.18	2.80
S_1A_3	3.51	1.20	2.95	2.98	2.66
S_2A_1	3.68	1.33	2.89	2.85	2.69
S_2A_2	3.72	1.36	3.10	3.19	2.84
S_2A_3	3.62	1.29	2.99	2.96	2.72
Mean	3.61	1.26	2.99	3.01	---

Spacings: SE_m = .03 C.D (.05) = .05

Alleys : SE_m = .03 C.D (.05) = .05 A_2 A_3 A_1

Orientation: SE_m = .02 C.D (.05) = .02 O_1 $\overline{O_4 \quad O_3}$ O_2

crop showed the maximum value (7.6) and the minimum being in the E-W orientation.

The effect of spacing as well as alleys was also significant. S_2 spacing recorded the highest value (6.3). Regarding alleys, A_2 gave the maximum value (6.3).

Among the interactions, S X A and S X A X O were significant. S_2 X A_2 had the highest value (6.5) among the S X A combinations. S_2 X A_2 X O_1 possessed the maximum leaf area index (8.2) among the S X A X O combinations.

On the 90th day after planting the orientation effect was highly significant. The N-S orientation showed the maximum value (5.7), the lowest (3.0) being in the E-W orientation.

Spacing as well as alleys significantly affected the leaf area index. S_2 spacing recorded the maximum value (4.8). The highest value (4.6) was observed for A_2 alleys.

Only the S X A interaction was found to be significant. S_2 X A_2 had the highest value (4.9) of leaf area index.

The analysis of variance table on the day of harvest shows that the effect of orientation was highly significant. The maximum leaf area index (3.6) was obtained in N-S orientation, the lowest value (1.3) being in the E-W orientation.

The effects of spacing and alleys were also significant. The leaf area index in S_2 was the highest (2.8). Regarding alleys the highest value (2.8) was found in A_2.

4. Number of productive tillers.

The analysis of variance table for the number of productive tillers is presented in Appendix XI and the mean values in Table 11.

The effect due to the different orientations was observed to be significant. Maximum number of productive tillers (375) was found in the N-S orientation. The lowest value (325) was in the NE-SW orientation.

The effect due to spacing was also highly significant. The mean number of productive tillers was the maximum (353) in S_1.

The effect of alleys was significant and the A_2 alleys recorded the maximum value (353) while the lowest (333) was in A_3.

Table 11

Number of productive tillers per square meter.

	O_1	O_2	O_3	O_4	Mean
S_1	383	327	333	367	353
S_2	366	378	316	371	333
A_1	379	333	314	345	343
A_2	384	339	332	355	353
A_3	360	310	328	332	333
S_1A_1	382	337	334	349	351
S_1A_2	394	337	334	399	366
S_1A_3	374	307	330	354	341
S_2A_1	375	329	294	342	335
S_2A_2	377	340	330	312	340
S_2A_3	347	314	325	310	324
Mean	375	328	325	344	--

Spacing : $SE_m = \pm 13$ C.D (.05) = 19.5

Alleys : $SE_m = \pm 13$ C.D (.05) = 19.5 $\overline{A_2 \; A_1} \; A_3$

Orientation: $SE_m = \pm 15.5$ C.D(.05) =16 $O_1 \; O_4 \; \overline{O_2 \; O_3}$

None of the interactions was found to be significant.

5. Length of panicle.

The analysis of variance table for the length of panicle is presented in Appendix XII and the mean lengths of panicles in Table 12.

The effect due to orientation was highly significiant. Among the various orientations the maximum length of panicle (24.1 cm) was noticed in the N-S orientation and the least value (10.9 cm) in the E-W orientation.

The effects due to spacing and alleys were found to be highly significant. The maximum (22.4 cm) was recorded in S_1. Regarding alleys the highest value (22.6 cm) occured in A_1 and the lowest (21.8 cm) in A_2.

All the interactions except S X A were not significant. The maximum value (23.0 cm) was recorded in S_1 X A_1 and the minimum (22.1 cm) in S_2 X A_1.

6. Number of grains per panicle.

The analysis of variance table for the number of grains per panicle is given in Appendix XIII and the mean values in Table 13.

Table 12

Length of panicle (cm)

	O_1	O_2	O_3	O_4	Mean
S_1	24.44	21.13	22.37	21.80	22.22
S_2	23.83	20.69	21.68	21.46	21.92
A_1	24.83	21.22	21.78	22.37	22.55
A_2	23.72	20.03	22.03	21.25	21.76
A_3	23.87	21.48	22.25	21.28	22.22
$S_1 A_1$	24.63	21.60	22.37	23.30	22.98
$S_1 A_2$	24.37	19.87	22.67	21.67	22.15
$S_1 A_3$	24.33	21.93	22.07	20.43	22.19
$S_2 A_1$	25.03	20.83	21.20	21.43	22.12
$S_2 A_2$	23.07	20.20	21.40	20.83	21.38
$S_2 A_3$	23.40	21.03	22.43	22.13	22.25
Mean	24.14	20.91	22.03	21.63	---

Spacing: $SE_m = \pm .27$ C.D(.05) = .4

Alleys : $SE_m = \pm .27$ C.D(.05) = .4 A_1 A_3 A_2

Orientation: $SE_m = \pm .75$ C.D(.05)=.38 O_1 $\overline{O_3 \ O_4}$ O_2

Table 12 (a)

Combined effect of spacing between plants and spacing between alleys on length of panicle (cm).

	A_1	A_2	A_3	Mean
S_1	22.98	22.14	22.19	22.44
S_2	22.13	21.38	22.25	21.92
Mean	22.55	21.76	22.22	---

SE_m = ± .27 C.D (.05) = .4

$S_1A_1 \quad \overline{S_2A_3 \quad S_1A_3 \quad S_1A_2 \quad S_2A_1} \quad S_2A_2$

Table 13

Number of grains per panicle

	O_1	O_2	O_3	O_4	Mean
S_1	130.80	111.77	124.11	124.40	122.77
S_2	111.73	100.05	106.02	107.40	106.35
A_1	125.83	115.80	121.45	121.20	121.07
A_2	120.65	101.05	114.62	115.28	112.90
A_3	117.32	100.87	109.13	111.22	109.64
S_1A_1	137.77	130.90	134.63	133.07	134.10
S_1A_2	127.27	101.03	121.80	121.33	117.86
S_1A_3	127.37	103.37	115.90	118.80	116.36
S_2A_1	113.90	100.70	108.27	109.33	108.05
S_2A_2	114.03	101.07	107.43	109.23	107.94
S_2A_3	107.27	98.37	102.37	103.63	102.91
Mean	121.27	105.91	115.07	115.90	---

Spacing: $SE_m = \pm .54$ C.D (.05) = .84

Alleys : $SE_m = \pm .54$ C.D (.05) = .84 A_1 A_2 A_3

Orientation: $SE_m = \pm 2.94$ C.D(.05)=3.43 O_1 $\overline{O_4 \quad O_3}$ O_2

Table 13 (a)

Combined effect of spacing between plants and spacing between alleys on number of grains per panicle

	A_1	A_2	A_3	Mean
S_1	134.09	117.86	116.36	122.77
S_2	108.05	107.94	102.91	106.35
Mean	121.07	112.90	109.64	---

SE_m = ± .54 C.D(.05)=.84 S_1A_1 S_1A_2 S_1A_3 S_2A_1 S_2A_2 S_2A_3

The effect of orientation was observed to be highly significant. The N-S oriented crop produced the highest number of grains per panicle (121). The lowest value was found in the E-W orientation (106). N-S oriented crop had about 15% more number of grains than that of E-W orientation.

The effect due to spacing as well as alleys were highly significant. The highest value (123) was in S_1. Regarding alleys A_1 recorded the maximum number of grains (121).

Among the interactions, only S X A combination was found to be significant. The highest mean value (134) was in S_2A_2.

7. Thousand grain weight.

Appendix XIV gives the analysis of variance of the thousand grain weight and Table 14 the mean values.

The effect due to orientation and S X A interaction alone were highly significant. The N-S orientation had the highest value (28.1 g) while the E-W orientation showed the lowest value (26.6 g).

Among the S X A combinations S_2 X A_2 interaction recorded the highest weight (28.0 g) of thousand grains.

Table 14

Thousand grain weight (g)

	O_1	O_2	O_3	O_4	Mean
S_1	28.07	26.17	27.41	26.72	27.09
S_2	28.16	26.98	27.40	26.60	27.29
A_1	28.35	26.80	27.45	25.93	27.13
A_2	27.73	25.90	27.95	26.98	27.14
A_3	28.25	27.02	26.82	27.07	27.29
S_1A_1	29.43	26.77	27.60	26.43	27.56
S_1A_2	26.27	24.57	27.57	26.50	26.23
S_1A_3	28.50	27.17	27.07	27.23	27.49
S_2A_1	27.27	26.83	27.30	25.43	26.71
S_2A_2	29.20	27.23	28.33	27.47	28.01
S_2A_3	28.00	26.87	26.57	26.90	27.09
Mean	28.12	26.58	27.41	26.66	--

Spacing: $SE_m = .44$

Alleys : $SE_m = .44$

Orientation: $SE_m = .64$ C.D(.05)= .75 $\underline{O_1 \quad \overline{O_3}}\ \overline{\underline{O_4 \quad O_2}}$

Table 14 (a)

Combined effect of spacing between plants and spacing between alleys on thousand grain weight(g)

	A_1	A_2	A_3	Mean
S_1	27.56	26.23	27.49	27.09
S_2	26.71	28.06	27.08	27.29
Mean	27.13	27.14	27.29	---

SE_m = ± .44 C.D (.05) = .69

$\overline{S_2A_2 \quad \underline{S_1A_1 \quad S_1\ A_3}}\underline{\quad S_2A_3} \quad \overline{S_2A_1 \quad S_1A_2}$

8. Grain yield.

The analysis of variance table for the grain weight is presented in Appendix XV and the mean values in Table 15.

The table shows that the effect due to orientation was highly significant. Maximum yield (3062 kg/ha) was obtained in N-S orientation. The next lower value was observed in NE-SW orientation. NW-SE and NE-SW orientations were on par with regard to the grain yield. The lowest value was found in the E-W orientation (2744 kg/ha). The grain yield in N-S was about 12% more than that in E-W. In NE-SW and NW-SE it was 6 - 7% more than the lowest figure. The grain yield of N-S orientation indicated that it was highest in almost all treatments of spacing between plants and spacing between alleys in comparison to E-W treatments.

Spacing between plants also significantly affected the grain yield. The maximum value (2903 kg/ha) was recorded in S_2.

The interaction effect did not show any significant difference.

9. Straw yield.

The analysis of variance table for straw weight is presented in Appendix XVI and the mean values in Table 16.

Table 15

Grain yield (Kg/ha).

	O_1	O_2	O_3	O_4	Mean
S_1	3014.25	2708.32	2858.78	2827.91	2852.32
S_2	3109.55	2777.76	2905.07	2920.51	2903.22
A_1	3078.68	2799.52	2910.66	2957.16	2936.51
A_2	3101.83	2725.68	2881.93	2829.84	2884.82
A_3	3005.19	2737.25	2853.20	2835.63	2857.82
S_1A_1	3043.96	2719.89	2858.78	2939.80	2890.61
S_1A_2	3043.96	2711.65	2916.65	2727.76	2862.51
S_1A_3	2954.84	2696.74	2800.91	2766.19	2804.67
S_2A_1	3113.41	2812.48	2905.07	2974.52	2951.37
S_2A_2	3055.54	2777.76	2962.94	2905.07	2925.33
S_2A_3	3159.70	2743.04	2847.20	2881.93	2907.97
Mean	3061.90	2743.60	2881.93	2874.22	---

Spacing: $SE_m = \pm 20.66$ C.D (.05) = 32.54

Alleys : $SE_m = \pm 20.66$

Orientation: $SE_m = \pm 37.14$ C.D(.05) = 53.08 O_1 $\overline{O_3 \quad O_4}$ O_2

Table 16

Straw yield (Kg/ha).

	O_1	O_2	O_3	O_4	Mean
S_1	4039.21	3549.59	3846.12	3873.75	3827.17
S_2	4245.85	3793.91	3915.64	3954.10	3977.38
A_1	4249.19	3788.15	3917.70	4077.88	4008.23
A_2	4160.56	3889.32	3936.76	3912.98	3924.91
A_3	4017.85	3537.77	3788.18	3750.92	3773.68
S_1A_1	4212.93	3734.73	3903.67	4143.49	3998.71
S_1A_2	4085.62	3602.29	4037.47	3937.93	3915.83
S_1A_3	3819.08	3311.75	3597.21	3539.84	3566.97
S_2A_1	4285.45	3841.58	3931.72	4012.26	4017.75
S_2A_2	4235.49	3776.36	3836.05	3888.03	3933.98
S_2A_3	4216.62	3763.79	3979.14	3962.01	3980.39
Mean	4142.53	3671.75	3880.88	3913.93	--

Spacing: $SE_m = \pm 6.58$

Alleys : $SE_m = \pm 6.58$

Orientation: $SE_m = \pm 7.82$ C.D(.05)= 9.12 O_1 O_4 O_3 O_2

Table 16 (a)

Combined effect of spacing between plants and spacing between alleys on straw yield (Kg/ha).

	A_1	A_2	A_3	Mean
S_1	3998.71	3915.83	3566.97	3827.17
S_2	4017.75	3933.98	3980.39	3977.37
Mean	4008.23	3924.91	3773.68	---

SE_m = ± 6.58 C.D (.05) = 10.37

S_2A_1 S_1A_1 S_2A_3 S_2 A_2 S_2 A_2 S_1 A_3

From the table it is seen that the effects due to orientation, spacing and alleys were highly significant. Among the different orientations N-S yielded significantly higher straw yield (4143 kg/ha) followed by NW-SE and NE-SW orientations. The least value (3672 kg/ha) was observed in the E-W orientation. The straw weight in N-S was about 13% more than that in E-W orientation. In NW-SE and NE-SW it was 6-7% higher than the lowest value.

Regarding the spacing, S_2 attained the highest straw yield (3977 kg/ha). A_1 alleys recorded the maximum value (4008 kg/ha).

Among the interactions, only that of S X A was found to be significant. The highest value (4018 kg/ha) was observed in S_2 X A_1.

10. Drymatter production.

The final drymatter produced in all the treatments was analysed and the analysis of variance table is given in the Appendix XVII and the mean values in Table 17.

It is seen that the effect of orientation is highly significant. The N-S oriented crop recorded the maximum (7204 kg/ha) drymatter production. The least value (6415 kg/ha) was observed in the E-W orientation.

Table 17

Drymatter Production (Kg/ha).

	O_1	O_2	O_3	O_4	Mean
S_1	7053.47	6257.46	6759.79	6697.67	6692.10
S_2	7355.40	6571.69	6931.82	6874.61	6933.38
A_1	7327.87	6554.34	7048.63	7029.03	6989.97
A_2	7262.39	6414.37	6818.69	6742.83	6809.57
A_3	7023.04	6275.02	6670.10	6586.55	6638.68
S_1A_1	7256.89	6454.62	6927.14	7071.29	6927.48
S_1A_2	7129.58	6309.27	6954.12	6715.69	6777.17
S_1A_3	6773.92	6008.49	6398.12	6306.02	6371.64
S_2A_1	7398.85	6654.06	7170.13	6986.78	7052.46
S_2A_2	7395.19	6519.46	6683.25	6769.96	6841.97
S_2A_3	7272.16	6541.55	6942.08	6867.08	6905.72
Mean	7204.44	6414.58	6845.81	6786.14	---

Spacing: SE_m = ± 16.23 C.D(.05) = 25.57

Alleys : SE_m = ± 16.23 C.D(.05) = 25.57 A_1 A_2 A_3

Orientation: SE_m = ± 13.74 C.D(.05) =15.04 O_1 O_3 O_4 O_2

Table 17 (a)

Combined effect of spacing between plants and spacing between alleys on drymatter Production (Kg/ha).

	A_1	A_2	A_3	Mean
S_1	6927.48	6777.17	6371.64	6692.10
S_2	7052.46	6841.97	6905.72	6933.38

$SE_m = \pm 16.23$ C.D(.05) = 25.57

$S_2A_1 \quad \overline{S_1A_1 \quad S_2A_3} \quad S_2A_2 \quad S_1A_2 \quad S_1A_3$

The drymatter production in N-S was about 9% more than that in the E-W orientation.

The effect due to spacing and alleys were found to be highly significant. The highest value (6933 kg/ha) was found in S_2.

Regarding alleys the maximum (6990 kg/ha) was found in A_1.

Among the interactions S X A combination showed significant difference. The maximum value (7053 kg/ha) was found in S_2 X A_1 and the lowest (6372 kg/ha) in S_1 X A_3.

11. Grain-straw ratio.

The analysis of variance table for the grain-straw ratio is presented in Appendix XVIII and the mean values in Table 18.

The effect of alleys and S X A interaction were only significant.

A_3 alleys recorded the maximum value (.76) of grain-straw ratio. Among the S X A combinations, S_1 X A_3 obtained the highest ratio (.79).

12. Nitrogen content.

The analysis of variance table for the nitrogen content is presented in Appendix XIX and the mean values in Table 19.

Table 18

Grain/Straw ratio

	O_1	O_2	O_3	O_4	Mean
S_1	.7477	.7661	.7447	.7327	.7478
S_2	.7330	.7328	.7421	.7391	.7368
A_1	.7259	.7317	.7356	.7265	.7299
A_2	.7455	.7393	.7327	.7237	.7353
A_3	.7496	.7774	.7618	.7576	.7616
S_1A_1	.7233	.7306	.7326	.7109	.7244
S_1A_2	.7455	.7522	.7228	.7056	.7315
S_1A_3	.7743	.8155	.7786	.7816	.7875
S_2A_1	.7285	.7328	.7387	.7421	.7355
S_2A_2	.7455	.7264	.7427	.7417	.7391
S_2A_3	.7249	.7393	.7450	.7337	.7357
Mean	.7403	.7495	.7434	.7359	---

Spacing: $SE_m = \pm .0234$

Alleys : $SE_m = \pm .0234$ C.D(.05)= .0268 $A_3\ \overline{A_2\ A_1}$

Orientation: $SE_m = \pm .0361$

Table 18 (a)

Combined effect of spacing between plants and spacing between alleys on grain/straw ratio.

	A_1	A_2	A_3	Mean
S_1	.7243	.7315	.7875	.7478
S_2	.7355	.7391	.7357	.7368
Mean	.7299	.7353	.7616	--

SE_m = ±.0234 C.D(.05)=.0268 S_1A_3 $\overline{S_2A_2\ S_2A_3\ S_2A_1\ S_1A_2\ S_1A_1}$

Table 19

Nitrogen Content (%).

	O_1	O_2	O_3	O_4	Mean
S_1	.92 (66.42)	.87 (60.16)	.92 (66.42)	.93 (68.99)	.91 (65.50)
S_2	.93 (68.99)	.87 (60.16)	.90 (63.85)	.90 (63.85)	.90 (64.21)
A_1	.93 (67.70)	.87 (60.16)	.90 (63.85)	.93 (67.70)	.91 (64.85)
A_2	.95 (71.56)	.87 (60.16)	.90 (63.85)	.90 (63.85)	.91 (64.86)
A_3	.90 (63.85)	.87 (60.16)	.93 (67.70)	.93 (67.70)	.91 (64.85)
S_1A_1	.90 (63.85)	.87 (60.16)	.90 (63.85)	.95 (71.56)	.91 (64.86)
S_1A_2	.95 (71.56)	.87 (60.16)	.90 (63.85)	.90 (63.85)	.91 (64.86)
S_1A_3	.90 (63.85)	.87 (60.16)	.95 (71.56)	.95 (71.56)	.92 (66.78)
S_2A_1	.95 (71.56)	.87 (60.16)	.90 (63.85)	.90 (63.85)	.91 (64.86)
S_2A_2	.95 (71.56)	.87 (60.16)	.90 (63.85)	.90 (63.85)	.91 (64.86)
S_2A_3	.90 (63.85)	.87 (60.16)	.90 (63.85)	.90 (63.85)	.89 (62.93)
Mean	.93 (67.71)	.87 (60.16)	.91 (65.14)	.92 (66.42)	---

Spacing: $SE_m = \pm 1.33$ C.D(.05) = 2.11

Alleys : $SE_m = \pm 1.34$

Orientation: $SE_m = \pm 2.17$ C.D(.05)= 2.53 $\overline{O_1 \quad \underline{O_4}}\underline{\quad O_3} \quad O_2$

Note: Transformed data in brackets.

Table 19 (a)

Combined effect of spacing between plants and spacing between alleys on nitrogen content (%).

	A_1	A_2	A_3	Mean
S_1	.91 (64.86)	.91 (64.86)	.92 (66.78)	.91 (65.50)
S_2	.91 (64.86)	.91 (64.86)	.89 (62.93)	.90 (64.21)
Mean	.91 (64.86)	.91 (64.86)	.91 (64.86)	---

$SE_m = \pm 1.34$ C.D (.05) = 2.11

$\overline{S_1A_3 \quad S_1A_1 \quad S_1A_2 \quad S_2A_1 \quad S_2A_2} \quad S_2A_3$

Note: Transformed data in brackets.

The effect due to orientation was found to be significant. Among different crop orientations mean nitrogen content was the highest (.93%) in N-S orientation and the lowest (.87%) in the E-W orientation.

The effect due to spacing was also significant. The spacing S_1 recorded the highest value (.91%).

Among the interactions S X A and S X O were significant. S_1 X A_3 recorded the highest nitrogen content (.92%) among the S X A combinations. S_2 X O_1 recorded the maximum value (.93%) regarding S X O combinations.

13. Phosphorous content.

The analysis of variance table corresponding to the phosphorous content is given in Appendix XX and the mean values in Table 20.

The effect due to different orientations was observed to be significant. The N-S oriented crop had the maximum value of phosphorous content (.43%), the E-W having the minimum (.31%).

The effect of spacing as well as alleys were also significant. S_2 spacing gave the highest phosphorous content (.38%). A_3 alleys showed the maximum value (.39%) regarding alley treatments.

Table 20

Phosphorous content (%).

	O_1	O_2	O_3	O_4	Mean
S_1	.40 (23.32)	.30 (17.60)	.35 (20.70)	.38 (22.28)	.36 (20.98)
S_2	.43 (25.70)	.31 (18.06)	.36 (21.10)	.42 (34.64)	.38 (22.38)
A_1	.41 (24.31)	.32 (18.46)	.36 (21.31)	.38 (22.33)	.37 (22.60)
A_2	.38 (22.57)	.28 (16.36)	.34 (19.69)	.38 (22.15)	.35 (20.20)
A_3	.45 (26.65)	.32 (18.66)	.37 (21.72)	.44 (25.90)	.39 (23.23)
S_1A_1	.43 (25.26)	.32 (18.66)	.38 (22.13)	.38 (22.54)	.38 (22.15)
S_1A_2	.34 (19.88)	.27 (15.46)	.31 (17.86)	.34 (19.68)	.32 (18.22)
S_1A_3	.42 (24.83)	.32 (18.66)	.38 (22.13)	.42 (24.62)	.39 (22.56)
S_2A_1	.40 (23.37)	.31 (18.26)	.35 (20.49)	.38 (22.13)	.36 (21.06)
S_2A_2	.42 (25.26)	.30 (17.26)	.37 (21.51)	.42 (24.63)	.38 (22.17)
S_2A_3	.48 (28.47)	.32 (18.66)	.36 (21.31)	.46 (27.17)	.41 (23.90)
Mean	.43 (25.70)	.31 (18.06)	.36 (21.10)	.42 (24.64)	--

Spacing: $SE_m = \pm .27$ C.D(.05) = .42

Alleys : $SE_m = \pm .27$ C.D(.05) = .42 A_3 A_1 A_2

Orientation: $SE_m = \pm .28$ C.D(.05)=.33 O_1 O_4 O_3 O_2

Note: Transformed data in brackets.

Table 20 (a)

Combined effect of spacing between plants and spacing between alleys on phosphorous content (%).

	A_1	A_2	A_3	Mean
S_1	.38 (22.15)	.32 (18.22)	.39 (22.56)	.36 (20.98)
S_2	.36 (21.06)	.38 (22.17)	.41 (23.9)	.38 (22.38)
Mean	.37 (21.60)	.35 (20.20)	.39 (23.23)	---

$SE_m = \pm .27$ C.D(.05)=.42 S_2A_3 $\overline{S_1A_3\ S_2A_2\ S_1A_1}$ S_2A_1 S_1A_2

Note: Transformed data in brackets.

All the interactions were found to be significant. S_1 X A_3 recorded the maximum phosphorous content (.41%) among S X A combinations. S_2 X O_1 showed the highest value (.43%) regarding S X O combinations. Among A X O interactions A_3 X O_1 got the highest phosphorous content (.45%). S_2 X A_3 X O_1 had the maximum value (.48%) among S X A X O.

14. Potassium content.

The analysis of variance table for the potassium content is presented in Appendix XXI and the mean values in Table 21.

The data reveal that the effect due to orientation was highly significant. N-S oriented crop recorded the maximum value of potassium content (.88%). The lowest value (.61%) was seen in the E-W orientation.

The effect of spacing was also significant. The spacing S_2 showed the maximum value of .77%.

The effect due to alleys was highly significant. A_1 had the highest potassium content (.75%).

All the interactions were also found to be significant. Among S X A combinations S_2 X A_2 showed

Table 21

Potassium content (%).

	O_1	O_2	O_3	O_4	Mean
S_1	.86 (58.97)	.66 (41.21)	.74 (47.59)	.85 (58.08)	.78 (51.46)
S_2	.92 (66.46)	.56 (34.33)	.78 (51.55)	.74 (47.59)	.77 (49.98)
A_1	.91 (66.03)	.55 (33.40)	.70 (44.60)	.76 (49.12)	.75 (48.29)
A_2	.90 (63.94)	.66 (41.62)	.81 (54.47)	.85 (58.55)	.82 (54.65)
A_3	.85 (58.18)	.62 (38.29)	.76 (49.64)	.76 (50.83)	.76 (49.24)
S_1A_1	.87 (60.56)	.62 (38.32)	.75 (48.59)	.84 (57.15)	.77 (51.16)
S_1A_2	.92 (67.63)	.77 (50.07)	.80 (53.13)	.92 (67.63)	.85 (59.62)
S_1A_3	.75 (48.72)	.58 (35.23)	.66 (41.05)	.76 (49.47)	.69 (43.62)
S_2A_1	.94 (71.50)	.48 (28.48)	.65 (40.61)	.66 (41.10)	.68 (45.42)
S_2A_2	.87 (60.24)	.55 (33.18)	.83 (55.81)	.76 (49.47)	.75 (49.68)
S_2A_3	.92 (67.63)	.66 (41.34)	.85 (58.22)	.79 (52.19)	.81 (54.85)
Mean	.88 (62.72)	.61 (37.77)	.76 (49.57)	.79 (52.84)	--

Spacing: $SE_m = \pm 1.45$ C.D(.05) = 2.28

Alleys : $SE_m = \pm 1.45$ C.D(.05) = 2.28 $A_2 \quad \overline{A_3 \quad A_1}$

Orientation: $SE_m = \pm 1.76$ C.D(.05) = 2.05 O_1 O_4 O_3 O_2

Note: Transformed data in brackets.

Table 21 (a)

Combined effect of spacing between plants and spacing between alleys on potassium content (%).

	A_1	A_2	A_3	Mean
S_1	.77 (51.16)	.85 (59.62)	.69 (43.62)	.78 (51.46)
S_2	.68 (45.42)	.75 (49.68)	.81 (54.85)	.77 (49.98)
Mean	.75 (48.29)	.82 (54.65)	.76 (49.24)	--

SE_m = ± 1.45 C.D(.05)=2.28 S_1A_2 S_2A_3 $\overline{S_1A_1\ S_2A_2}$ $\overline{S_2A_1\ S_1A_3}$

Note: Transformed data in brackets.

the maximum value (.85%). S_2 X O_1 recorded the highest content of potassium (.92%) among the S X O combinations. A_1 X O_1 gave the highest value (.91%) among the A X O interactions. The maximum value (.94%) was obtained in the S_2 X A_1 X O_1 among the combinations.

15. Uptake of nitrogen in the harvested crop.

The analysis of variance table coresponding to the uptake of nitrogen is given in Appendix XXII and mean values in Table 22.

The effect due to orientation was observed to be highly significant. N-S oriented crop showed the maximum uptake of nitrogen (66.5 kg/ha), the minimum (55.6 kg/ha) being in the E-W orientation.

The effect of spacing as well as alleys was also significant. S_2 spacing recorded the highest value (62.3 kg/ha). Regarding alleys A_1 gave the maximum uptake of nitrogen (63.1 kg/ha).

Among the interactions S X O, A X O and S X A X O were observed to be significant. S_2 X O_1 recorded the highest value (68.4 kg/ha) among S X O combinations. Regarding A X O interaction A_2 X O_1

Table 22

Uptake of Nitrogen (Kg/ha).

	O_1	O_2	O_3	O_4	Mean
S_1	64.46	54.23	61.66	62.29	60.66
S_2	68.44	56.94	62.12	61.64	62.29
A_1	67.56	56.79	63.14	64.79	63.07
A_2	68.80	55.60	61.12	60.48	61.50
A_3	62.98	54.36	61.40	60.62	59.84
S_1A_1	65.10	55.95	62.07	66.92	62.51
S_1A_2	67.51	54.68	62.32	60.25	61.19
S_1A_3	60.75	52.05	60.59	59.70	58.27
S_2A_1	70.02	57.63	64.20	62.66	63.63
S_2A_2	70.09	56.52	59.93	60.72	61.82
S_2A_3	65.20	56.67	62.22	61.54	61.41
Mean	66.45	55.59	61.89	61.97	---

Spacing: SE_m = ± 1.79 C.D(.05) = 1.62

Alleys : SE_m = ± 1.79 C.D(.05) = 1.62 A_1 A_2 A_3

Orientation: SE_m = ± 1.37 C.D(.05)=1.60 O_1 $\overline{O_4\quad O_3}$ O_2

showed the maximum uptake of nitrogen (68.8 kg/ha). Among the S X A X O combinations, S_2 X A_2 X O_1 was found to have the maximum value (70.1 kg/ha).

16. Uptake of phosphorous in the harvested crop.

The analysis of variance table for the uptake of phosphorous in presented in Appendix XXIII and the mean values Table 23.

The effect due to orientation was observed to be highly significant. The highest value was recorded in the N-S orientation and the lowest being in the E-W.

Spacing as **well** as alleys had a significant effect on the uptake of phosphorous. S_2 spacing had the highest value (26.5 kg/ha). Regarding alleys A_3 recorded the maximum uptake of phosphorous (26.8 kg/ha).

All the interaction effects were found to be significant. S_2 X A_3 showed the maximum value (28.1 kg/ha) among S X A combinations. Regarding S X O combinations S_2 X O_1 had the highest value (31.9 kg/ha) of phosphorous uptake. Among the A X O interactions A_3 **X** O_1 recorded the highest value (31.6 kg/ha). S_2 X A_3 X O_1 gave the maximum value (34.7 kg/ha) of phosphorous uptake among the S X A X O combinations.

Table 23

Uptake of Phosphorous (Kg/ha).

	O_1	O_2	O_3	O_4	Mean
S_1	27.88	18.91	23.84	25.33	23.99
S_2	31.86	20.38	24.95	28.63	26.46
A_1	30.15	20.77	25.61	26.71	25.81
A_2	27.90	18.08	22.91	25.41	23.56
A_3	31.56	20.09	24.65	28.82	26.28
S_1A_1	30.96	20.67	26.10	27.10	26.21
S_1A_2	24.24	16.83	21.31	22.60	21.25
S_1A_3	28.45	19.23	24.10	26.28	24.52
S_2A_1	29.35	20.87	25.13	26.32	25.42
S_2A_2	31.55	19.34	24.50	28.21	25.90
S_2A_3	34.67	20.94	25.20	31.37	28.05
Mean	29.87	19.65	24.40	26.98	--

Spacing: $SE_m = \pm 2.60$ C.D (.05) = 2.1

Alleys : $SE_m = \pm 2.60$ C.D (.05) = 2.1 $\overline{A_3 \quad A_1}$ A_2

Orientation: $SE_m = \pm 1.05$ C.D(.05)= 1.23 O_1 O_4 O_3 O_2

Table 23 (a)

Combined effect of spacing between plants and spacing between alleys on the uptake of phosphorous (Kg/ha).

	A_1	A_2	A_3	Mean
S_1	26.21	21.25	24.51	23.99
S_2	25.42	25.90	28.05	26.46
Mean	25.81	23.56	26.28	---

SE_m = ± 2.60 C.D(.05) = 2.1

$\overline{S_2A_3\ \underline{S_1A_1}}\underline{\ S_2A_2\ S_2A_1\ S_1A_3}\ S_1A_2$

17. Uptake of potassium in the harvested crop.

The analysis of variance table is given in Appendix XXIV and the mean values in Table 24.

The effect of orientation was highly significant. N-S oriented crop showed the highest value (63.5 kg/ha), the lowest being in the E-W (38.9 kg/ha).

The effect due to alleys was also significant. A_2 alleys recorded the maximum value (54.8 kg/ha).

All the interactions were observed to be significant. S_1 X A_2 gave the maximum value (58.0 kg/ha) among the S X A combinations. A_1 X O_1 recorded the highest value (66.5 kg/ha) among the A X O combinations. Regarding S X O interaction S_2 X O_1 had the maximum uptake of potassium (67.0 kg/ha). S_2 X A_1 X O_1 combination attained the highest value of potassium uptake (69.8 kg/ha) due to the S X A X O interaction.

18. Albedo.

Observations on crop albedo were recorded at fortnightly intervals from the completion of the vegetative phase onwards and are presented in Tables 25 to 29 and depicted graphically in Figures 5 to 8.

Table 24

Uptake of Potassium (Kg/ha).

	O_1	O_2	O_3	O_4	Mean
S_1	59.95	41.01	49.87	56.45	51.82
S_2	67.03	36.86	54.78	50.52	52.30
A_1	66.49	35.90	49.33	52.63	51.09
A_2	64.98	41.99	55.44	56.74	54.79
A_3	58.99	38.91	52.20	51.09	50.30
S_1A1	63.16	40.01	52.00	59.39	53.64
S_1A_2	65.85	48.37	55.63	62.02	57.97
S_1A_3	50.83	34.64	42.01	47.93	43.85
S_2A_1	69.82	31.79	46.71	45.87	48.55
S_2A_2	64.12	35.61	55.24	51.46	51.61
S_2A_3	67.14	43.17	62.38	54.24	56.73
Mean	63.49	38.94	52.33	53.49	---

Spacing: $SE_m = \pm 1.80$ C.D(.05) = 2.83

Alleys : $SE_m = \pm 1.80$ C.D(.05) = 2.83 $A_2 \quad \overline{A_1 \quad A_3}$

Orientation: $SE_m = \pm .54$ C.D(.05) = .78 $O_1 \quad O_4 \quad O_3 \quad O_2$

Table 24 (a)

Combined effect of spacing between plants and spacing between alleys on the uptake of potassium (Kg/ha).

	A_1	A_2	A_3	Mean
S_1	53.63	57.97	43.85	51.82
S_2	48.55	51.61	56.74	52.30
Mean	51.09	54.79	50.30	---

$SE_m = \pm 1.80$ C.D(.05) = 2.83

$\overline{S_1A_2 \quad S_2A_3} \quad \overline{S_1A_1 \quad S_2A_2} \quad S_2A_1 \quad S_1A_3$

Table 25

Average day time variation of albedo on different treatments

on 14-12-1983. (75 days after planting)

	Time							
	7.30	9.00	10.30	12.00	13.30	15.00	16.30	Mean
O_1	43.9	27.7	24.8	19.4	19.1	21.6	22.7	25.6
O_2	37.4	25.7	21.8	16.7	16.2	18.4	19.5	22.2
O_3	41.6	26.9	23.9	17.6	17.9	19.3	21.2	24.1
O_4	41.5	26.5	22.4	17.0	17.7	19.9	21.5	23.8
S_1	39.2	26.2	21.2	18.4	16.9	18.6	20.5	23.0
S_2	43.1	28.4	23.9	18.0	16.9	18.5	21.8	24.4
A_1	41.4	26.8	22.9	18.4	17.2	18.8	21.3	23.8
A_2	41.1	28.6	23.8	19.2	18.6	20.5	23.9	25.1
A_3	40.5	26.5	21.1	17.1	14.9	16.4	18.4	22.1

Table 26

Average day time variation of albedo on different treatments on 28-12-1983.

				Time				
	7.30	9.00	10.30	12.00	13.30	15.00	16.30	Mea
O_1	32.2	26.7	21.4	19.5	18.3	20.5	22.5	23.
O_2	25.0	21.3	16.9	17.1	16.6	18.0	20.3	19.
O_3	28.0	22.8	19.0	18.5	17.7	18.1	21.6	20.
O_4	27.5	22.5	18.7	18.1	17.5	18.9	21.8	20.
S_1	30.8	25.0	19.8	19.0	17.9	18.8	22.4	22.
S_2	38.3	29.3	23.9	20.8	19.0	20.5	25.0	25.
A_1	34.5	24.6	22.7	19.6	18.4	19.9	24.1	23.
A_2	35.7	28.7	23.0	20.8	18.5	20.2	24.5	24.
A_3	34.0	28.2	21.4	19.4	18.4	19.0	22.7	23.

Table 27

Average day time variation of albedo on different treatments on 11-1 1984.

	Time							
	7.30	9.00	10.30	12	13.30	15.00	16.30	Mea
O_1	33.8	25.3	17.7	17.4	17.6	18.1	23.4	21.
O_2	27.0	22.8	16.0	15.8	16.6	17.1	20.2	19.
O_3	30.9	24.1	17.0	16.3	16.9	17.8	21.7	20.
O_4	30.5	23.8	17.0	15.9	16.7	18.0	22.0	20.
S_1	33.5	26.5	25.6	23.1	19.9	21.4	22.9	24.
S_2	40.2	34.0	30.0	22.8	20.8	22.6	25.2	27.
A_1	36.7	28.9	27.2	21.6	19.5	20.8	24.4	25.
A_2	37.8	31.8	29.1	25.0	21.4	21.4	24.8	27.
A_3	36.2	30.2	27.2	22.4	20.1	21.9	23.0	25.

Table 28

Average day time variation of albedo on different treatments on 25-1-1984.

	Time							
	7.30	9.00	10.30	12.00	13.30	15.00	16.30	Mea
O_1	29.3	20.9	19.9	18.2	14.8	16.0	19.0	19.
O_2	27.0	19.1	18.4	15.6	13.5	15.0	16.2	17.
O_3	28.3	19.7	19.1	16.8	14.0	15.5	17.3	18.
O_4	27.5	19.4	18.9	16.1	13.8	15.8	18.0	18.
S_1	28.0	23.7	20.4	18.0	15.4	16.9	18.9	20.
S_2	34.3	22.4	20.2	18.9	16.0	19.2	19.6	21.
A_1	32.6	22.4	20.2	17.8	14.5	17.7	19.0	20.
A_2	31.8	26.4	21.8	19.8	17.7	18.8	20.6	22.
A_3	29.2	20.5	19.0	17.3	14.9	17.3	18.3	19.

Table 29

Average day time variation of albedo on different treatments at harvest (on 8-2-1984).

	7.30	9.00	10.30	12.00	13.30	15.00	16.30	Me
O_1	27.3	23.0	14.8	14.3	15.4	16.0	17.4	18.
O_2	27.3	23.0	14.8	14.3	15.4	16.0	17.4	18.
O_3	27.3	23.0	14.8	14.3	15.4	16.0	17.4	18.
O_4	27.3	23.0	14.8	14.3	15.4	16.0	17.4	18.
S_1	27.3	23.0	14.8	14.3	15.4	16.0	17.4	18.
S_2	27.3	23.0	14.8	14.3	15.4	16.0	17.4	18.
A_1	27.3	23.0	14.8	14.3	15.4	16.0	17.4	18.
A_2	27.3	23.0	14.8	14.3	15.4	16.0	17.4	18.
A_3	27.3	23.0	14.8	14.3	15.4	16.0	17.4	18.

Table 30

Total radiation, reflected radiation and albedo at different growth stages of the rice crop in different orientations.

	14.12.83	28.12.83	11.1.84	25.1.84	7.2.84
Total radiation					
	8.5	7.0	8.3	8.9	8.7
Reflected radiation					
O_1	2.18	1.61	1.82	1.75	1.59
O_2	1.89	1.35	1.61	1.67	1.59
O_3	2.05	1.46	1.72	1.66	1.59
O_4	2.02	1.45	1.71	1.62	1.59
Albedo					
O_1	25.6	23.0	21.9	19.7	18.3
O_2	22.2	19.3	19.4	18.8	18.3
O_3	24.1	20.8	20.7	18.7	18.3
O_4	23.8	20.7	20.6	18.2	18.3

Total radiation, reflected radiation and albedo at different growth stages in different orientations are presented in Figure 9. Variation of albedo and the leaf area index at different growth stages in also given in Figures 10.

It is seen that albedo varies with time of the day as well as with the pregress of the crop. During the day the albedo is the maximum at 0730 hr. for all orientations and decreases to a minimum after 12 noon and increases again thereafter. The maximum albedo was observed over the N-S oriented rows and the minimum over the E-W oriented rows.

The albedo before the heading stage was 25.6 percent and it decreased to 18.3 percent at harvest. The albedo values gradually decreased as the crop matured and attained almost constant values for all orientations during maturity and harvest.

When the albedo over the spacing between plants and spacing between alleys are considered, it is seen that the values, while keeping the usual pattern of variation during the day, exhibit the maximum over S_2 and A_2 and the minimum over S_1 and A_1.

DISCUSSION

DISCUSSION

The results of the observations made in the investigation on the influence of crop geometry on the growth and yield of rice are discussed below:

1. Crop growth characters.

1.1. Height of plants.

The results indicate that at all the stages of the observations the plants in N-S orientation were significantly taller than those in other orientations. Increase in height in these plants might be due to more uniform distribution of radiation. This is in agreement with the findings of Florell(1929) and Dhanil (1966). In the E-W orientation plant height is comparitively less. Here in the morning the plants on the east end of the line shade their adjacent plants in their immediate west while in the evening the situation is reverse. This could be the possible reason for lesser utilisation of solar radiation and thereby reduced plant height in the E-W orientation. Medium height of plants in NW-SE and NE-SW orientations could be due to moderate and partial capture of solar radiation in these orientations. Similar results were obtained in the studies of Dungan *et al.* (1955), Shekhawat *et al.* (1966) and Dhillon and Kler (1981), and Murthy(1982).

Regarding the spacing effects, as the plant density increased, the height also increased on the 30th day after planting. Since the plants are grown closely sunlight cannot reach the base of the plants and this leads to accleration of internodal elongation in the early stages. Similar results are recorded at Indian Agricultural Research Institute (Anon 1968).

On the 60th day after planting and at the time of harvest wider spacing 20 cm X 15 cm produced significantly taller plants. In these plants the competition for nutrient absorption per plant being low, it might have been in excess of the quantity actually required for the growth. The nutrients might have been utilised for the vegetative growth of plants resulting in the height increase in the later stages. This confirms the findings of Tanaka *et al.* (1964).

2. Number of tillers.

The results clearly point out that the number of tillers were more in N-S orientation as comparied to E-W, NW-SE and NE-SW orientations at all stages of crop growth. Tillering in N-S oriented plants is favoured by more uniform distribution of radiation. The results are in agreement with the findings of Khalil (1956) and Rawson (1971).

The number of tillers was maximum with S_1 spacing (20 cm X 15 cm). It was also found that $S_1 X O_1$ combination was most beneficial with regard to tiller production. In wider spacing overcrowding and competition for nutrients were reduced and the light transmission was better. Similar results were obtained in the experiments conducted at the Regional Agricultural Research Station, Pattambi (Anon 1975). This also confirms the findings of Shahi *et al.* (1977).

The mean number of tillers was increasing till about 60 days after planting and there was a decrease in the number subsequently. This decrease might be due to overcrowding and serious mutual shading which resulted in the death of many weak tillers and lower leaves, because of their failure in getting sufficient light and nutrients. Similar results were observed by Matsushima (1957) and Izhizuka and Tanaka(1963).

3. Leaf area index.

There is an optimum leaf area for maximum production above which increase in leaf area has no positive effect on productivity (Dhillon et al. 1978). The higher leaf area helps in better absorption of radiation and thus in higher drymatter production and yield. Experimental results (Tables 7, 8, 9 and 10) show that among all the orientations N-S oriented crop increased the leaf area index at all stages of crop growth. More uniform distribution of radiation in the N-S oriented plants increased the leaf area index. This is in agreement with the findings of Osada et al. (1972).

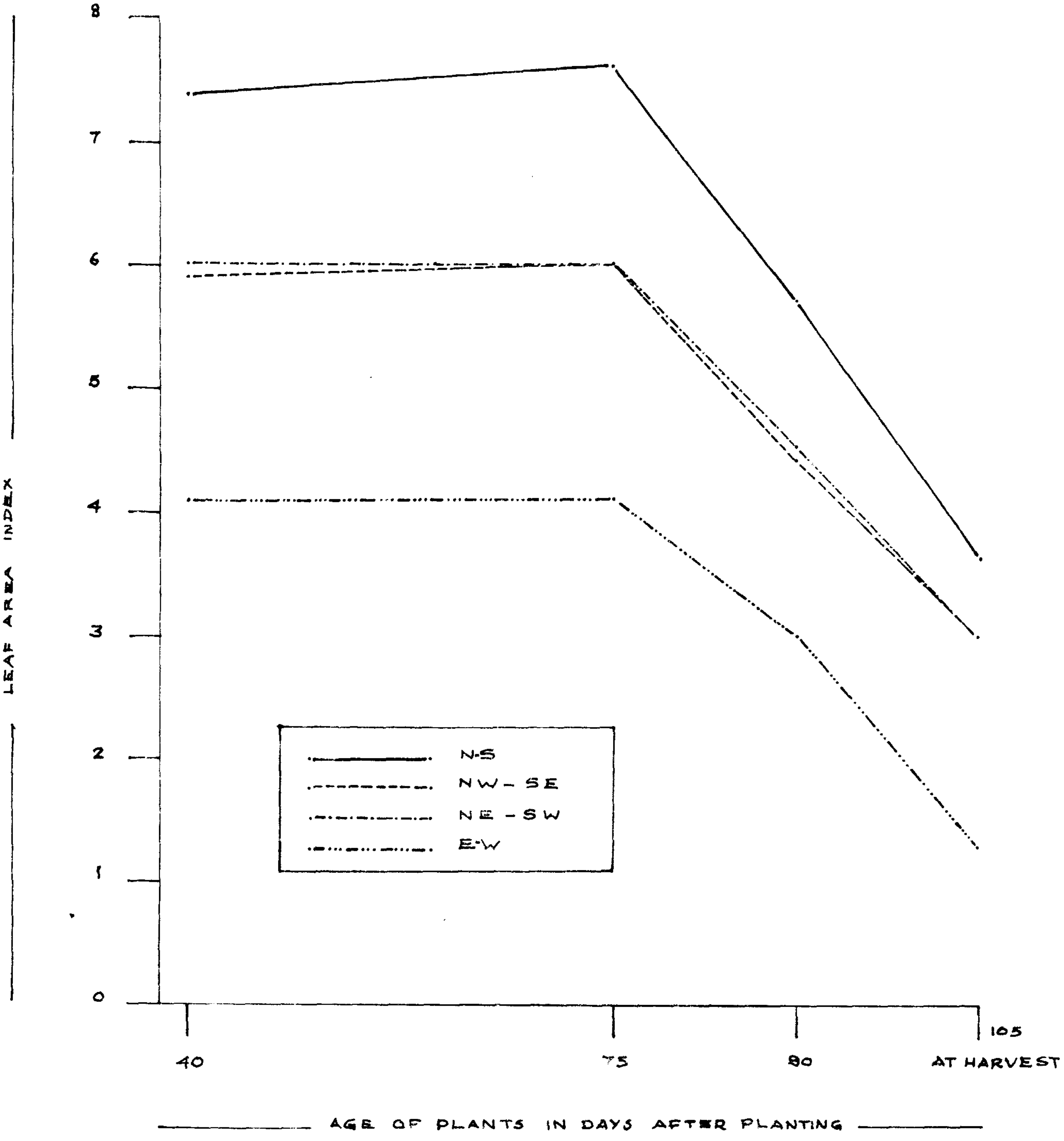
Closer spacing has contributed to an increase in leaf area index. It assures a leaf area index sufficiently large for maximum crop photosynthesis.

4. Number of productive tillers.

Number of productive tillers has a positive correlation with grain yield. The results reveal that the number of productive tillers were more in N-S orientation in comparison with other orientations. The possible reason to produce more effective tillers is the uniform utilisation of solar energy. The results closely agree with the findings of Khalil (1956) and Rawson (1971).

FIG: 3 LEAF AREA INDEX AT VARIOUS GROWTH STAGES

SCALE 2 cm = 1



An increase in number of productive tillers was noticed at wider spacing. This too might be attributed to the proper utilisation of solar energy unlike in the case of closer spacing. The results are similar to the findings in Regional Agricultural Research Station, Pattambi (Anon 1973).

5. Length of panicle.

Length of panicle also was maximum in the N-S orientation. This might be due to better exposure of crops to solar radiation in N-S direction.

The length of panicle increased with wider spacing. Decrease in plant population density assured a better light transmission which in turn has contributed to a remarkable increase in panicle length. Studies by Hedayatullah and Sen (1944), Vacchani et al.(1961) and Mahapatra and Paddalia (1963) also reveal the same results.

6. Number of grains per panicle.

Number of grains per panicle, one of the important components of yield, was significantly higher in the N-S oriented rows than in others. As in the case of other characters the N-S orientation has helped to attain greater efficiency in proper utilisation of radiant energy which resulted in more number of grains per panicle.

Wider spacing also significantly enhanced this component. Smaller population density enabled better exposure to sunlight and hence better overall growth and development of plant. Tanaka (1958) observed the existence of a relationship between overcrowding of fields and reduction in the number of grains per panicle. At closer spacing and subsequent overcrowding, the carbohydrate requirement of the plant is not fully met and the number of grains per unit area is adjusted to the number which is just adequate to store the substances produced by the plant. Yamada (1961) recognised that the proportion of nonphotosynthetic area in the plant was increased by plant density and the amount of starch in the plant body was low and filling percentage was decreased. Similar results have also been obtained in studies conducted at Regional Agricultural Research Station, Pattambi (Anon 1973).

7. Thousand grain weight.

The thousand grain weight is a reliable index of seed development and consequently of grain yield and its quality. When compared with other orientations, it was significantly higher in the N-S orientation. Better exposure of crops to solar radiation in this direction resulted in higher grain weight. The results confirm the findings of Dhillon *et al*. (1978) and Dhillon and Kler (1981).

8. Grain yield.

Analysis of the data indicated that orientation of rows had a significant effect on grain yield. It was the highest in N-S orientation and the lowest in the E-W oriented crop. The yield figures from the NW-SE and NE-SW orientations were in between these two.

In rice, all the leaves from the flag leaf down to the third leaf from the top export assimilates to the panicle while the lower leaves send their assimilates to the roots (Tanaka 1958). In the N-S orientation there was greater advantage in the effective utilisation of solar radiation. Flag leaves, the main suppliers of photosynthates to earhead, were more exposed to sunlight which resulted in increased grain yield. Sandhu (1964), Sharma and Sing (1971) and Murthy (1982) have reported similar results in wheat. The better growth and development of the plants in the N-S oriented crop is evident from the greater leaf area index, greater number of productive tillers, longer panicles, more number of filled grains per panicle etc. On the other hand the plants grown in E-W orientation were less developed and of reduced vigour.

Among the spacing treatments S_2 spacing (20 cm X 10 cm) was significantly superior to S_1. Spikelet number, which is one of the yield components, was increased by increasing plant density. At closer spacing, the yield per plant is less, but this is compensated by greater number of plants per unit area. Moreover, closer spacing has proved to be more favourable for rice production during the second crop season (Anon 1975). The results also agree with the findings of Lerch (1976).

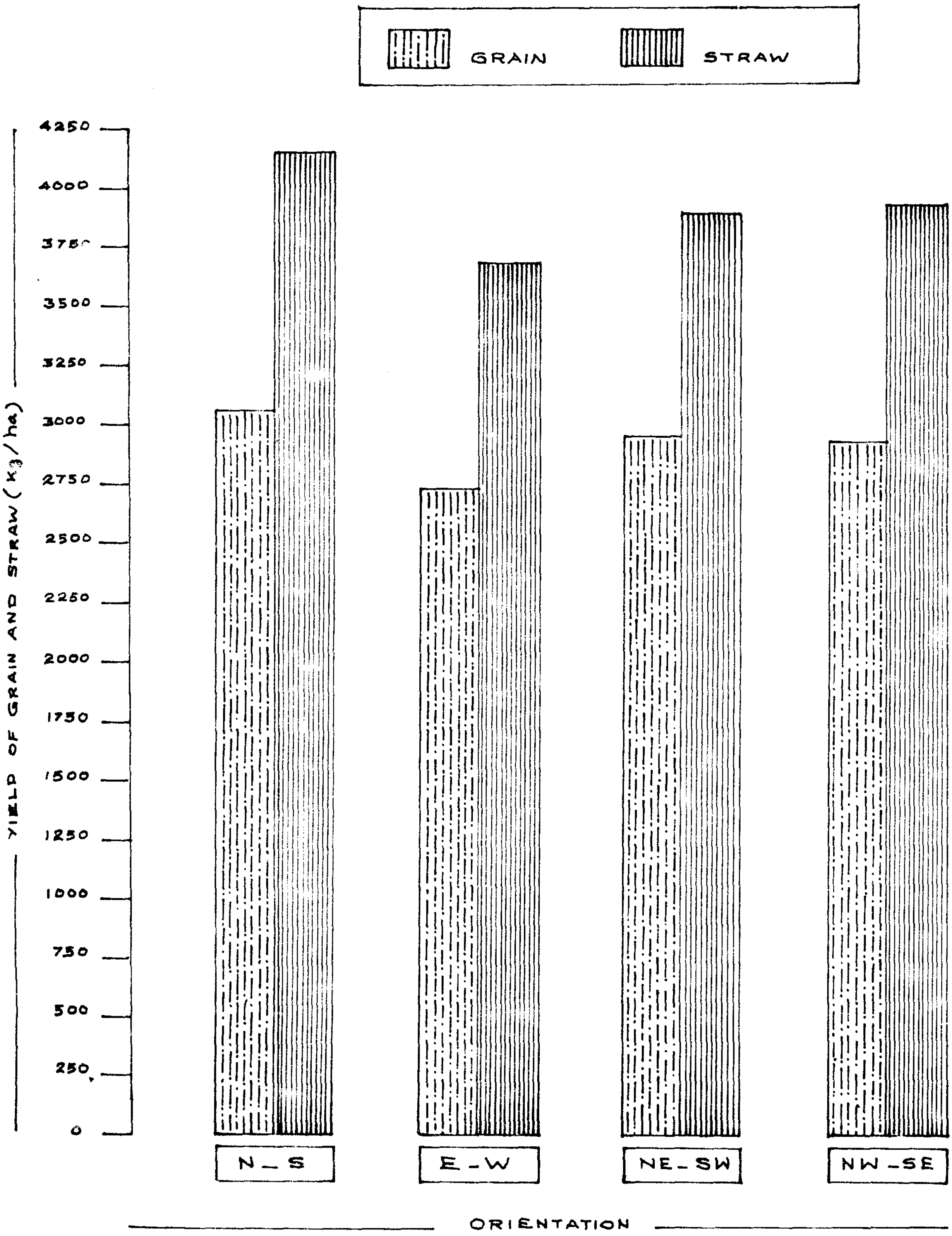
9. Straw yield.

N-S oriented crop recorded significantly higher value of straw yield in comparison with other orientations. This may be attributed to better vegetative growth under conditions of effective utilisation of light as decribed earlier. Similar results have been reported by Dungan *et al*. (1955) and Dhillon *et al*. (1978).

Closer spacing have significantly increased the straw yield. Here, more number of plants might have contributed to an increase in the straw yield. This also agrees with the findings at Regional Agricultural Research Station, Pattambi (Anon 1975).

FIG: 4 YIELD OF GRAIN AND STRAW
EFFECT OF ORIENTATION

SCALE 1 cm = 250 kg / hectare.



10. Drymatter production.

Analysis of the final drymatter brought out the significant difference in production by the different orientations. The N-S oriented crop has accumulated more drymatter than the others. Better development of both vegetative and reproductive phases of plant has ultimately reflected in higher accumulation of drymatter. The results confirm the findings of Dungan *et al.* (1955) and Dhillon *et al.* (1978) who observed around 20 percent more drymatter production in N-S orientation than that in the E-W orientation.

S_2 spacing, A_2 alleys and S_2 X A_2 combination were significantly superior with regard to drymatter production. This may be attributed to the high leaf area index in closer spacing, which resulted in more drymatter accumulation. The findings of Singh (1966), Tomar and Mathur (1966) and Lerch (1976) also confirm this.

11. Grain - Straw ratio.

Grain - Straw ratio did not show any significant difference due to orientation as well as spacing. However, It was significantly influenced by alleys, the maximum being in A_3. Although the overall development in A_3 was less than that of others, the weight of grain in relation to that of straw seems to have increased resulting in an increase in the grain - straw ratio.

12. Nitrogen, phosphorous and potassium contents.

Orientation and spacing significantly influenced the nutrient contents of plants. N-S oriented crop has the highest contents of nitrogen, phosphorous and potassium. Effective utilisation of radiation might have contributed to the better growth and development in those plants which in turn increased the nutrient content.

The nutrient availability per plant have increased with wider spacing resulting in high nitrogen content. On the other hand, closely spaced plants showed the higher values of phosphorous and potassium contents.

13. Uptake of nutrients.

Uptake of nutrients was also significantly influenced by orientation and spacing. Maximum values have been observed in the N-S orientation and S_2 spacing. Here again, the optimum conditions for the better growth and development of plants in the N-S orientation favoured the nutrient uptake. Increased plant density has also contributed to increased uptake of nitrogen, phosphorous and potassium.

14. Albedo.

A part of the radiation falling on the canopy is reflected back to space, the amount of which is determined by the albedo. It depends on the absorption coefficient and scattering function of leaves, their orientation and depth of crop stand. Crop albedo in fact is the combination of both crop and soil albedo. The change in the albedo during the growing season mainly depends upon the geometry and structure of the plant population.

The maximum albedo observed (Tables 25 to 29 and Figures 5 to 8) over the N-S oriented rows could be attributed to the denser canopy which is due to better growth and development of plants. The crop cover in these rows were substantial, thereby offering larger reflecting surface. The plant in the E-W orientation were less developed and hence the albedo values were smaller.

As the crop progressed in age, substantial changes occured in the canopy structure. The change in albedo during the rice growing season will depend upon the reflectance of the crop material mainly the leaves, the area of the flooded soil which is exposed to the sky, the leaf arrangement of the crop and solar elevation. The decrease in the albedo by the canopy according to the growth stage may be attributed to the decrease in the leaf area index, height and to such

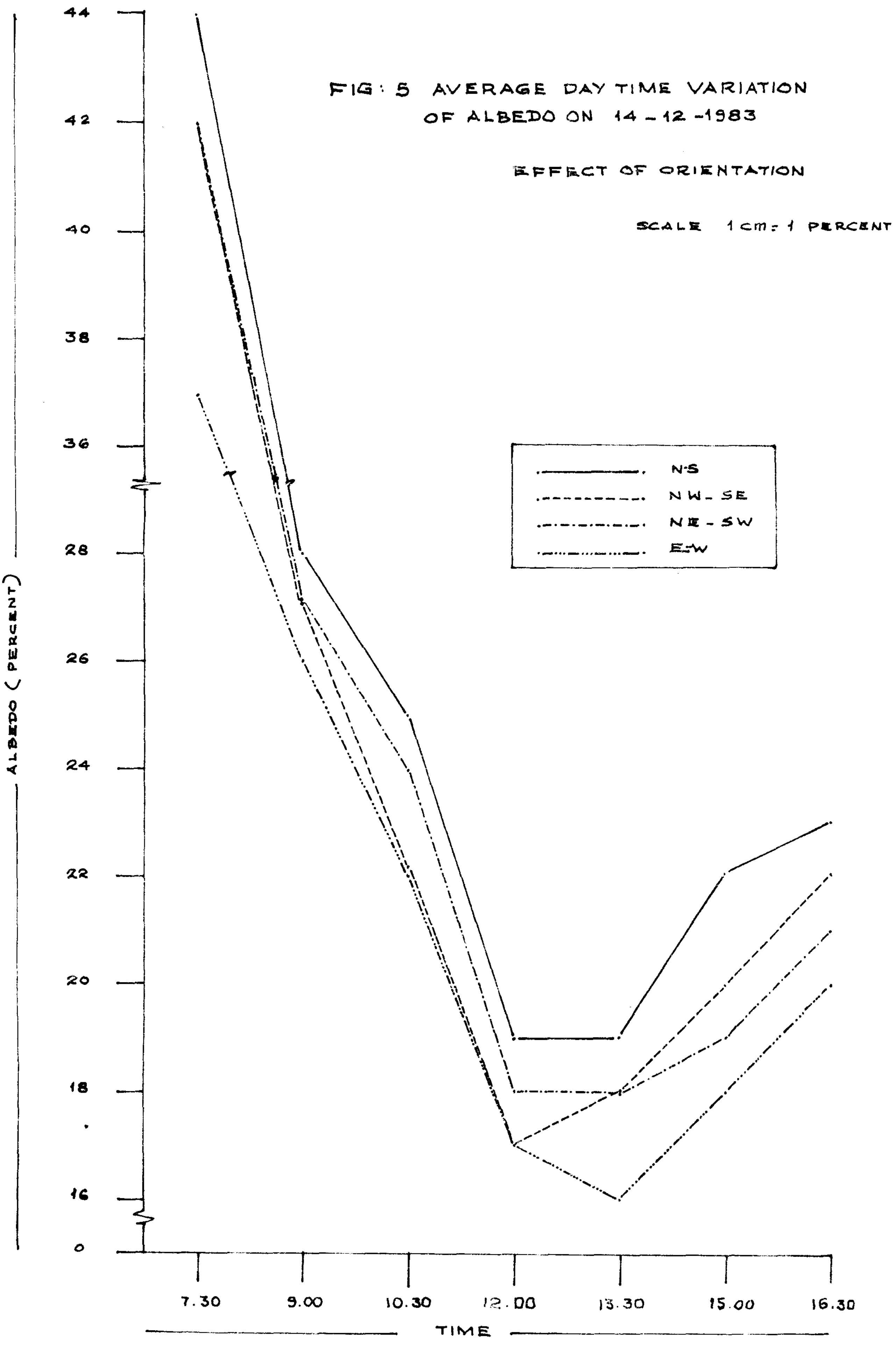


FIG: 5 AVERAGE DAY TIME VARIATION OF ALBEDO ON 14-12-1983

EFFECT OF ORIENTATION

SCALE 1 cm = 1 PERCENT

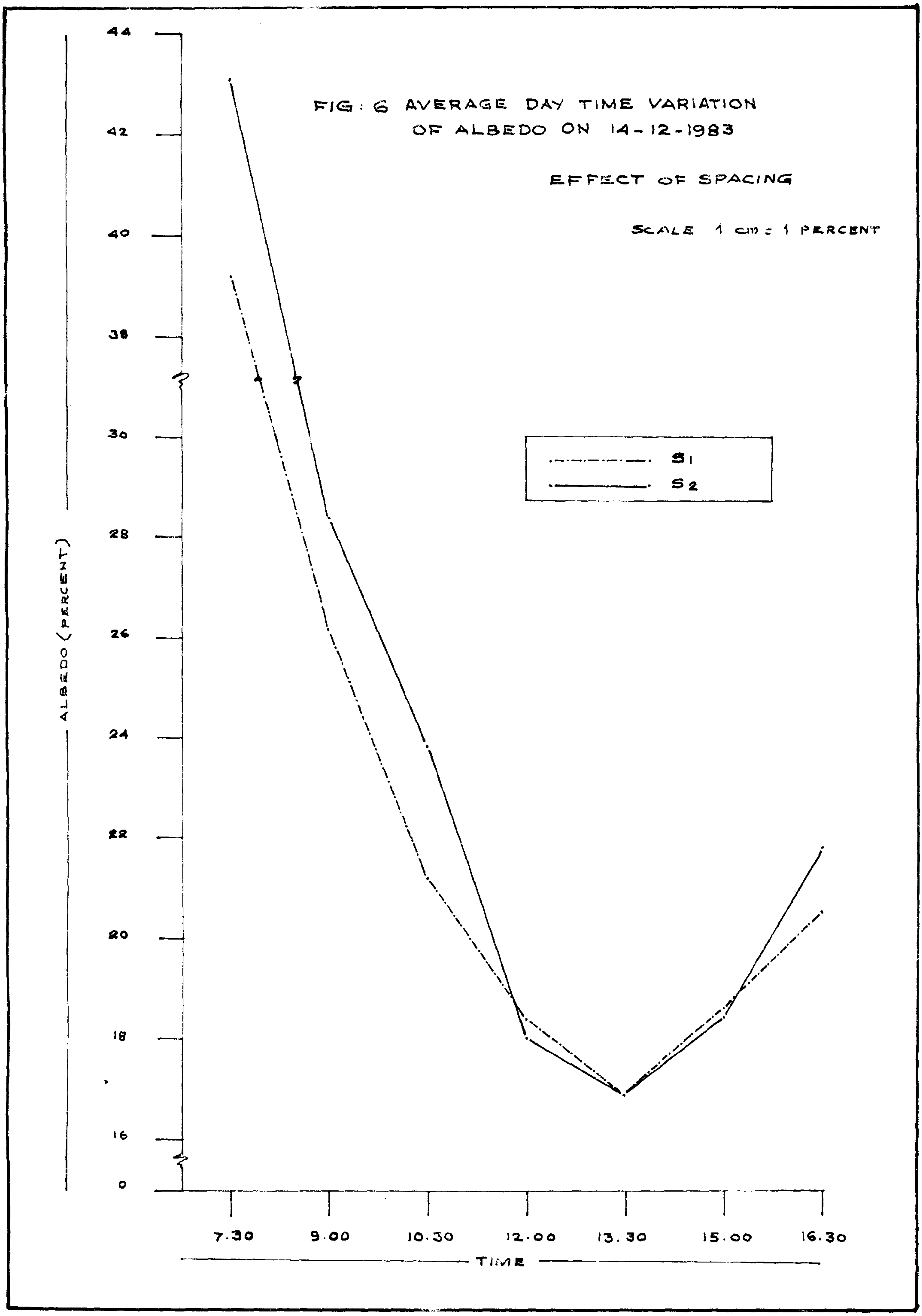


FIG: 6 AVERAGE DAY TIME VARIATION OF ALBEDO ON 14-12-1983

EFFECT OF SPACING

SCALE 1 cm = 1 PERCENT

FIG. 7 AVERAGE DAY TIME VARIATION OF ALBEDO ON 11-1-1984

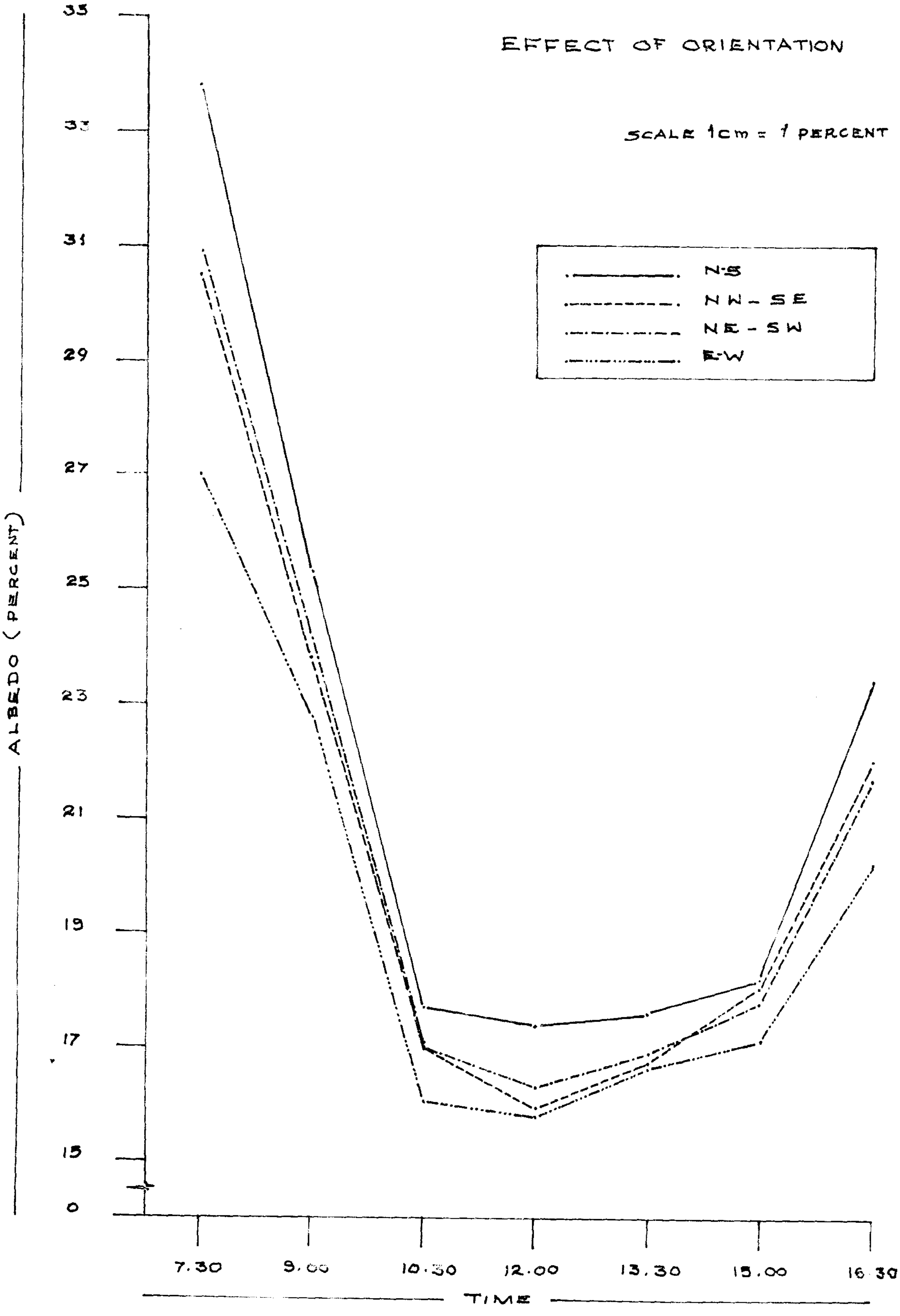
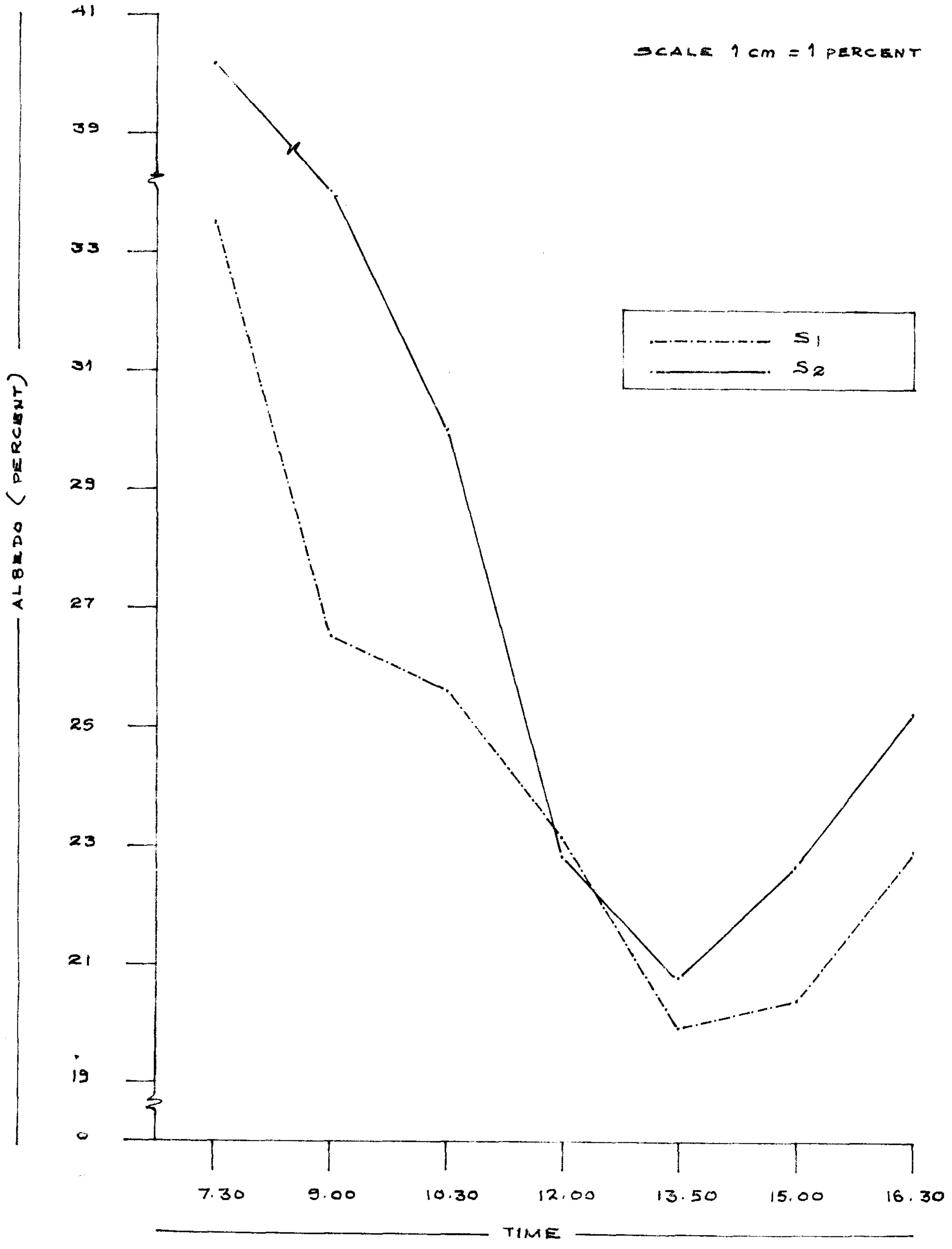


FIG: 8 AVERAGE DAY TIME VARIATION OF ALBEDO ON 11-1-1984

EFFECT OF SPACING

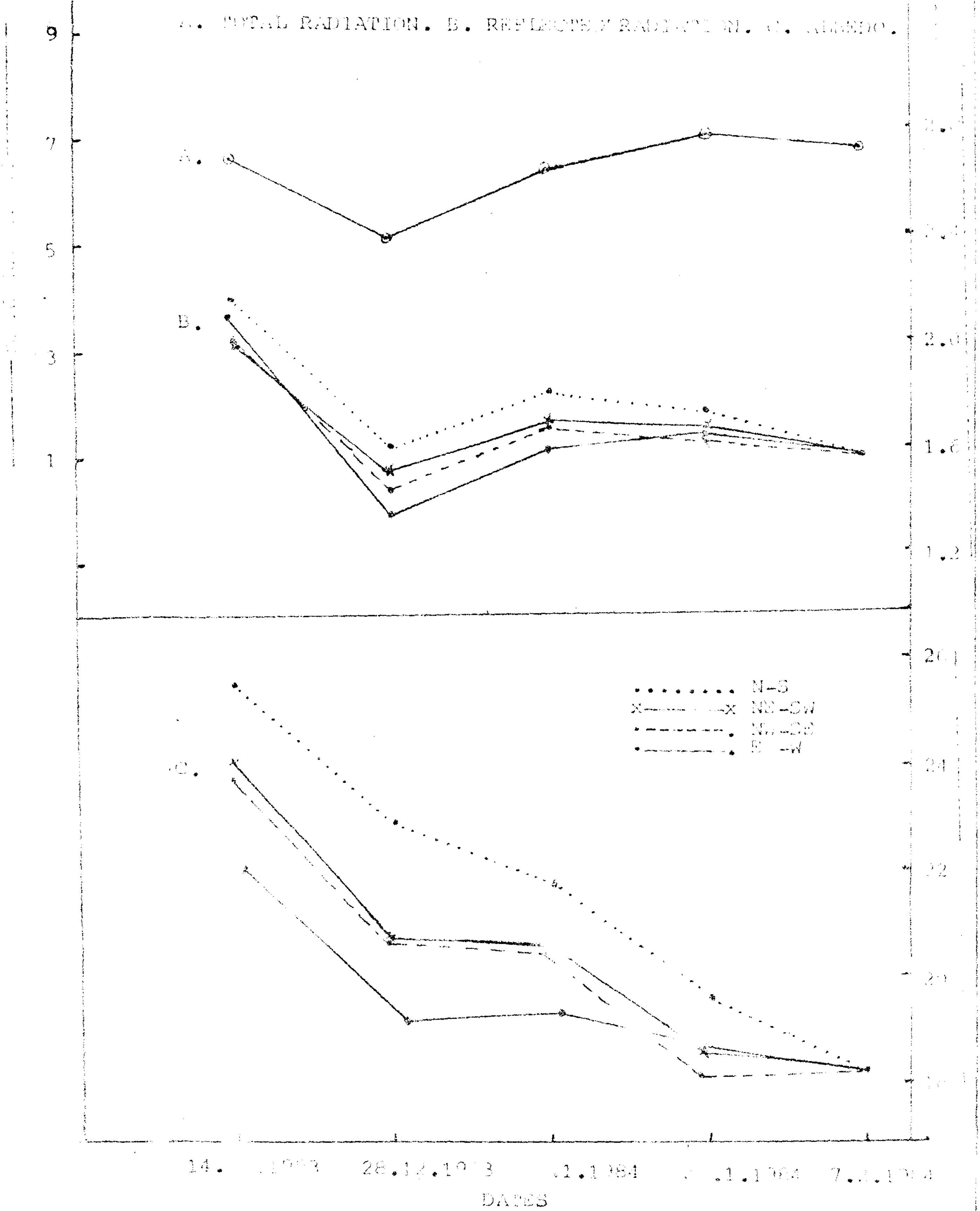


changes in the structure of the crop stand (Vamadevan, 1971). The albedo before the heading stage was 25.6 percent and it decreased gradually after heading to reach 18.3 percent at harvest (Table 30). During maturity period the leaves shrank in size and changed their colour slowly towards yellow and remained constant subsequently. As a result the albedo values did not very significantly between the treatments and the values showed similar pattern of variation with time within the day. These results are in full agreement with the findings of Goudrain (1977); who found that the fraction of radiation intercepted by a layer with certain leaf area is proportional to the average projection and inversely proportional to the sine of inclination of the incident radiation. The albedo values gradually decreased as the leaf area decreased (Figures 10). This is in agreement with the findings of Murata _et al_. (1968).

Spacing also has got a profound influence on the albedo. The higher values of albedo in closely spaced treatments can be attributed to denser canopy development. The relation between incident radiation and net photosynthesis by crops depends on the leaf area index and canopy structure. As is evident from Tables

FIG.9. TOTAL RADIATION, REFLECTED RADIATION AND ALBEDO AT DIFFERENT GROWTH STAGES IN DIFFERENT ORIENTATIONS.

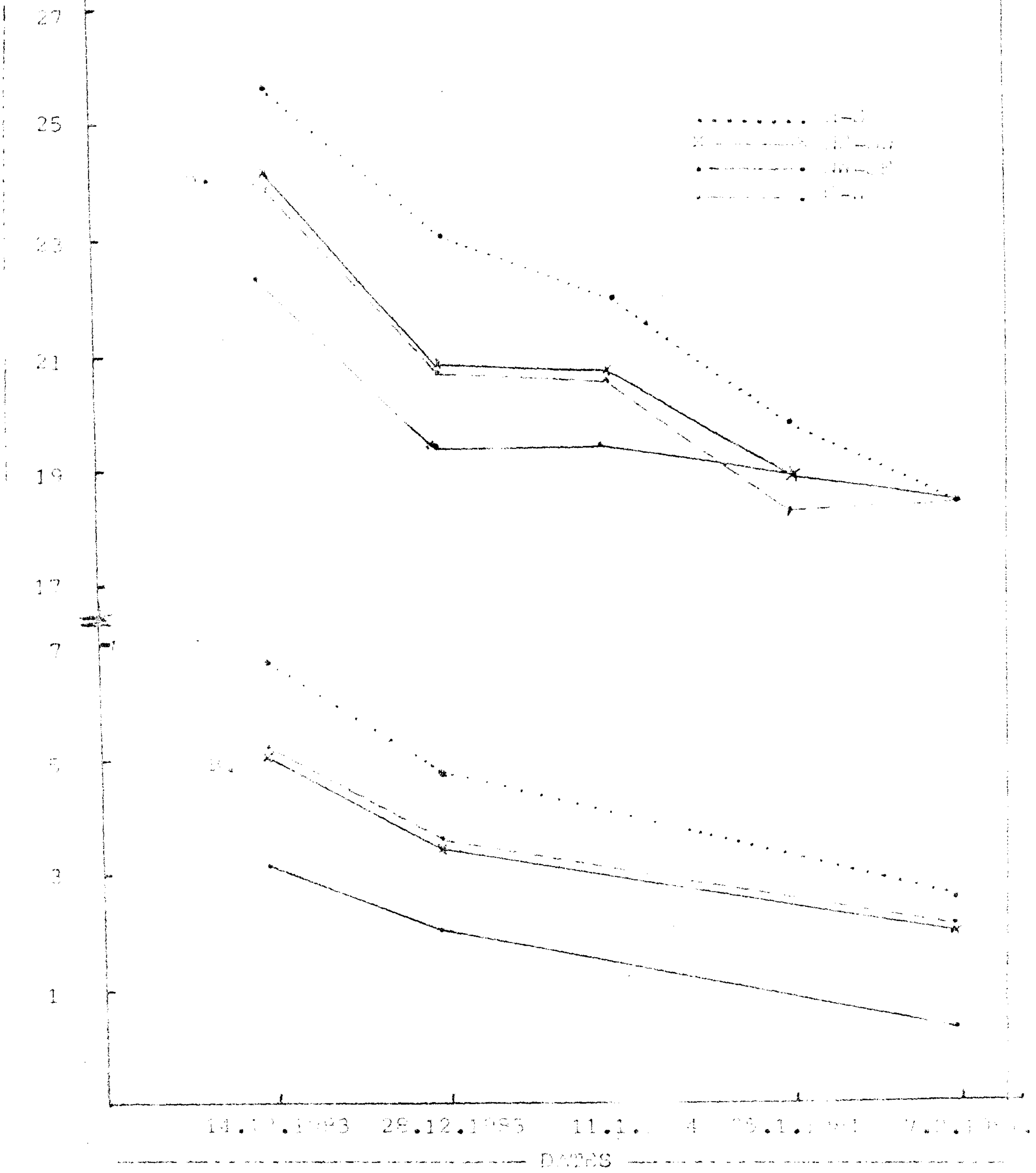
A. TOTAL RADIATION. B. REFLECTED RADIATION. C. ALBEDO.



[illegible].10. [illegible]

GROWTH STAGES [illegible]

[illegible]. [illegible]



7, 8, 9 and 10 leaf area index is higher in closely planted plots. The higher leaf area helps in better absorption of radiation, thus higher drymatter production and yield. This is in agreement with the findings of Asbertin and Peters (1961).

15. Influence of weather elements on crop performance.

At Pattambi the weather conditions during the entire growth period of the crop were more or less normal and congeneal. Hazardous weather was not experienced at all. A brief discussion of the influence of the individual meteorological factors on the crop performance is presented below:

1.. Temperature.

During the period of its growth, the present crop experienced temperature varying from about 20°C minimum to 34°C maximum and which according to Owen (1971) is the optimum range of temperature for rice. The optimum temperature for height and leaf development are 30°C and 25°C respectively while the requirement for tillering is 32 to 34°C (Mastsuo,1959). These conditions prevailed during the vegetative periods and so the growth in height, leaf development and tiller production were quite normal. The temperature during panicle initiation and anthesis ranged from

23 to 33°C which is about the optimum for these physiological processes (Best, 1959; Owen, 1971). During ripening the temperature ranged from 19 to 34°C which again is about the optimum for ripening according to Ebata and Negata (1967).

2. Sunshine.

The weather data reveals that the crop could enjoy bright sunny weather throughout its life except the initial stages soon after transplanting. The sunny weather, especially during flowering, was very helpful, because most of the grain yield comes from the post-flowering photosynthesis (Sato,1956).

3. Humidity.

Rice crop requires fairly high humidity for proper growth. Flowering is reported to be best when it is about 70 to 80 percent relative humidity and this crop experienced more or less similar humidity conditions during that time.

4. Rainfall.

The critical growth stages for water needs of rice are tiller initiation, primordial initiation and flowering (Srinivasan and Banerjee, 1973);

Choudhery and Ghildyal (1976); Subha Rao *et al.* (1976). It is seen that the crop under study received sufficient rainfall during these stages. The few days before harvest were marked by the absence of rainfall, during which the period the grain could mature properly in bright sunny weather with high temperature.

5. *Wind*.

An examination of Table 1 shows that throughout the life period of the crop wind velocity was never too high to cause adverse effect.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

An experiment was conducted at the Regional Agricultural Research Station, Pattambi during the second crop season of 1983 to study the influence of crop geometry on the growth and yield of rice variety 'Jaya'.

Plant characters like height, number of tillers and leaf area index at different stages of growth and yield attributes like number of productive tillers, length of panicle, number of grains per panicle, thousand grain weight and yield of grain and straw were observed and recorded. Nitrogen, phosphorous and potassium contents of plants were also determined and the uptake was worked out. The day time variation of albedo over different treatments was also recorded.

The main findings are summarised as follows:

1. Height of plants at all stages of its crop growth in the N-S orientation was significantly higher than those of other orientations. Wider spacing of 20 X 15 cm produced significantly taller plants.

2. Tiller production was maximum in the N-S oriented rows. There was significant increase in tiller production at wider spacing of 20 X 15 cm.

3. Significantly higher leaf area index was observed in the N-S orientation. Closer spacing of 20 X 10 cm

increased the leaf area index.

4. An increase in the number of productive tillers was noticed in the N-S orientation. Wider spacing of 20 X 15 cm recorded significantly more number of productive tillers.

5. There was significant increase in the length of panicle with N-S orientation. Wider spacing of 20 X 15 cm was significantly superior in increasing the length of panicle.

6. N-S orientation and wider spacing gave the highest number of grains per panicle.

7. The maximum weight of thousand grains was recorded in the N-S orientation. Closer spacing of 20 X 10 cm also showed the maximum weight of thousand grains.

8. Highest grain yield was obtained from the N-S oriented plots. Closer spacing also helped to increase the grain yield.

9. Straw yield was also higher in the N-S orientation. Among the spacing treatments S_2 (20 X 10 cm) spacing gave the maximum.

10. Maximum drymatter production was observed in the N-S oriented plots. There was also significant increase in the drymatter production with closer spacing of 20 X 10 cm.

11. Grain-straw ratio increased with wider spacing between alleys.

12. N-S oriented plants had the highest contents of nitrogen, phosphorous and potassium. Significant increase in nitrogen content was observed with wider spacing while phosphorous and potassium contents were maximum with closer spacing of 20 X 10 cm.

13. Maximum uptake of nutrients was observed in the N-S orientation. There was significant increase in the uptake of nutrients with closer spacing (20 X 10 cm).

14. The maximum albedo was recorded over the N-S oriented plots and also with closer spacing of 20X10 cm.

From this study, it can be concluded that rice in Kerala during the second crop season can be grown most successfully if planted at a spacing of 20 X 10 cm and oriented in N-S direction.

REFERENCES

REFERENCES

Ahmed, N.K. and Rao, R.S. 1966. The influence of cultural practices on panicle in japonica x indica hybrid rice. Ind. J. Agron. XI (2): 115-118.

Allen, L.H. 1974. A model of light penetration into a wide row crop. Agron. J. 66: 41-47.

Anderson, M.C. 1969. A comparison of two theories of scattering radiation in crops Agri. Met. 6 (6): 399-406.

Anonymous, 1964. Annual report. International Rice Research Institute, Philippines.

Anonymous, 1965. Annual report. International Rice Research Institute, Philippines.

Anonymous, 1967. Radiation balance of paddy field. J. Agr. Met. 3 (2): 99-102.

Anonymous, 1973. Nitrogen viariety spacing trials. Progress report of the All India Co-ordinated Rice Improvement Project.

Anonymous, 1973. Annual report. Regional Agricultural Research Station, Pattambi.

Anonymous, 1975. Annual report. Regional Agricultural Research Station, Pattambi.

Asbertin, G.M. and Peters, D.B. 1961. Net radiation determination in a corn field. Agron. J. 53: 269-272.

Bains, K.S. and Singh, S.P. 1967. Effect of fertiliser, spacing and number of seedlings per hill on paddy yield under low hill conditions. Ind. J. Agron. XII (2):

Best, R. 1959. Photoperiodism in rice. Field Crop Abstracts. 12 (2): 85-93.

Bhan, V.M. 1967. Effect of spacing on grain crops. Ind. J. Agron XII (2) : 145-150.

*Boysen Jensen, P. 1932. Die Soffproduktion der pflanzen. Fisher. Jena : 108.

Chandler, R.F. 1965. Factors affecting rice yields. Rice News Teller 13 : 2.

Chaudhary, T.N. and Ghildayal, B.P. 1976. Influence of submerged soil temperature regime on growth, yield and nutrient composition of the rice plant. Agron. J. 62 : 281-285.

De Datta, S.K. Tauro, A.C. and Balaoing, S.N. 1968. Effect of plant type and nitrogen level on the growth characteristics and yield of indica rice in the tropics. Agron. J. 60: 643-647.

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

Denmead, O.T., Fritschen, L.J. and shaw, R.H. 1962. Spatial distribution of net radiation in a corn field. Agron. J. 54 : 501-510.

Denmead, O.T. 1969. Comparitive micrometeorology of a wheat field and a forest of Pinus radiata. Agromet. 6 : 357-361.

Devi, G.D., Vijayagopal, P.D. and Sasidhar, V.K. 1981. Effect of levels of nitrogen and spacing on the yield of rice. Agri. Res. J. Kerala. 19 (2) : 96-97.

Dhillon, G.S. Kler, D.S., Waalia, A.S. and Randhawa, S.S. 1978. Utilisation of solar energy for crop production. Absts. Symposium on biological application of solar energy, Madhurai, on 5th December 1978 : 13-14.

*Dhillion, G.S. and Kler, D.S. 1981. Relation of shape of canopy to interception of radiation and yield of wheat. J. Agric. Sci. Camb. 97: 135-142.

*Donald, C.M. and Davison, J. L. 1958. The growth of swards of subterranean clover with particular reference to leaf area. Aust. J. Agr. Res. 9: 53-72.

*Duncan, W.G. 1968. Cultural manipulation for higher yields. Physiological aspects of crop yields. ed. J.D. Eastin et al. American society of Agronomy, Wisconsin: 327-339.

Duncan, W.G. 1971. Leaf angle, leaf area, and canopy photosynthesis. Crop Sci. 11: 482-485.

Dungan, G.H.,Sisodia, U.S. and Singh, G.D. 1955. The benefit of sowing maize for fodder in North and South lines. Allahabad Farmer. 29: 8-13.

Ebata, M. and Negata, K. 1967. Ripening conditions and grain characteristics of rice. IRC. Newsletter,special Issue: 10-15.

Fagade, S.C. and De Datta, S.K. 1971. Leaf area index, tillering capacity and grain yield of tropical rice as affected by plant density and nitrogen level. Agron. J. 63: 503-506.

*Florell, V.H. 1929. Effect of date of sowing on yield, lodging, maturity, and nitrogen content in cereal varietal experiments. J. Amer. Soc. Agron. 21: 724-731.

*Goudrain, J. 1971. Crop micrometeorology a stimulation study: A simulation study centre for agricultural publishing and documentation Wageningen: 249.

Goutam, D.E., Dasmahapatra, A.N. and Chatterjee, B.N. 1984. Transplanting of rice with skip rows. Indian. J. Agric. Sci. 54 (4): 280-283.

*Hanyu, J. 1966. Bull. Tohoku. Agr. Exp. St. Part -1. 34: 27-36.

*Kishida, Y. 1973. Agrometeorological studies on utilisation of radiant energy under cultivated field conditions. Bull. Kyushu. Agric. Exp. Stn. 27: 1-79.

Kulandaivelu, R. 1967. Studies on the response of ADP-27 rice to graded doses of nitrogen and spacing. MSc (Ag) Dissertation. University of Madras, unpublished.

*Lei, H.S. and Xi, D.B. 1967. On tillering rate of rice plant. Acta. Biol. Exp. Sinica. 8 (1): 35-44.

*Lerch, G. 1976. Effect of some climatic and agronomic factors on yield formation in rice cv. IR-8 in Cuba. Kulturpflanze. 24: 13-51.

Linvill, D.E. and Dale, R.F. 1975. Population density and sampling location effects on Net Radiation measurements over corn. Agron. J. 67 (4): 463-468.

Mahapatra, I.C. and Paddalia, C.R. 1963. A note on spacing and plant population in rice. Oryza. 1(2).

Mandal, B.B. and Mahapatra, I.C. 1968. Studies on the cultural and manurial requirements of some varieties of rice. Oryza. 5: 10-19.

*Matsuo, T. 1959. Rice culture in Japan. Pub. Min. Agr., Japan.

*Matuso, T. 1964. Varietal responses to nitrogen and spacing. Proceedings of a symposium at the International Rice Research Institute, February 1964, Maryland: 437-448.

*Matsushima, S. 1957. Analysis of development factors determining yield and yield prediction in lowland rice. Bull. Nat. Inst. Agr. Sci. Jap. A. 5: 1-271.

Monteith, J.L. 1972. Solar radiation and productivity in tropical ecosystems. J. Appl. Ecol. 9:747-766.

Monsi, M. and Saeki, T. 1953. Uber den Licht faktor in den planzengeselle chaften und Saine Bedevtung fur die stoffproduktion. Jap. J. Bot. 14: 22-52.

Moomaw, J.C., Baldazo, P.G. and Lucas, L. 1967. Effects of ripening period environment on yields of tropical rice. Int. Rice. Comm. Newsl : 18-25.

*Murata, Y., Osada, A. and Iyama, J. 1957. Studies on the photosynthesis in rice plant. Proc. Crop Sci. Soc. Jap. 26: 159-164.

*Murata, Y. 1961. Studies on the photosynthesis of rice plants and its culture significance. Bull. Nat. Inst. Agr. Sci. D. 9: 1-169.

*Murata, Y. 1964. On the influence of solar radiation and air temperature upon the local differences in the productivity of paddy rice in Japan. Proc. Crop Sci. Soc. Jap. 35: 59-63.

Murata, Y. 1966. On the influence of solar radiation and air temperature upon the local differences in the productivity of paddy rice in Japan. Int. Rice Comm. Newsl. 15: 20-30.

Murthi, V.R.K. 1982. A study of the role of meteorological factors in wheat crop production in the Punjab. M.Sc. Thesis, Punjab Agricultural University, Ludhiana.

Nair, P.K.R. 1968. Studies on the comparitive performance of three high yielding varieties of rice (IR-8, Tainan-3 and PTB-9) at varying levels of nitrogen and spacing under Trivandrum conditions. M.Sc. Thesis, Kerala University, Unpublished.

Nguu, N.V. and De Datta, S.K. 1979. Increasing effeciency of fertiliser nitrogen in wet land rice by manipulation of plant density and plant geometry. Field Crops Res. 2: 19-34.

Monsi, M. and Saeki, T. 1953. Uber den Licht faktor in den planzengeselle chaften und Saine Bedevtung fur die stoffproduktion. Jap. J. Bot. 14: 22-52.

Moomaw, J.C., Baldazo, P.G. and Lucas, L. 1967. Effects of ripening period environment on yields of tropical rice. Int. Rice. Comm. Newsl : 18-25.

*Murata, Y., Osada, A. and Iyama, J. 1957. Studies on the photosynthesis in rice plant. Proc. Crop Sci. Soc. Jap. 26: 159-164.

*Murata, Y. 1961. Studies on the photosynthesis of rice plants and its culture significance. Bull. Nat. Inst. Agr. Sci. D. 9: 1-169.

*Murata, Y. 1964. On the influence of solar radiation and air temperature upon the local differences in the productivity of paddy rice in Japan. Proc. Crop Sci. Soc. Jap. 35: 59-63.

Murata, Y. 1966. On the influence of solar radiation and air temperature upon the local differences in the productivity of paddy rice in Japan. Int. Rice Comm. Newsl. 15: 20-30.

Murthi, V.R.K. 1982. A study of the role of meteorological factors in wheat crop production in the Punjab. M.Sc. Thesis, Punjab Agricultural University, Ludhiana.

Nair, P.K.R. 1968. Studies on the comparitive performance of three high yielding varieties of rice (IR-8, Tainan-3 and PTB-9) at varying levels of nitrogen and spacing under Trivandrum conditions. M.Sc. Thesis, Kerala University, Unpublished.

Nguu, N.V. and De Datta, S.K. 1979. Increasing effeciency of fertiliser nitrogen in wet land rice by manipulation of plant density and plant geometry. Field Crops Res. 2: 19-34.

*Osada, A., Nara, M., Dhammanuvong, S., Rahony, M. and Gesprosert, M. 1972. The effect of seasons on the growth of indica rice in tropical area. Proc. Crop Sci. Soc. Jap. 41(2): 87-88.

Owen, P.C. 1971. The effect of temperature on the growth and development of rice - A review. Field Crop Abstracts. 24: 1-8.

Panse, V.G. and Sukhatme, P.V. 1954. Statistical methods for agricultural workers. ICAR Publication.

Parashar, K.S. 1976. Effect of spacing on the yield of rice. Ind. J. Agron. 21(4): 467-468.

*Perekaljskii, F.M. 1951. Direction of the drills of a sown area. Selek Semonovod. 18: 70-73.

Pendleton, J.W. and Dungan, G.H. 1958. Effect of row direction on spring Oat yields. Agron. J. 50: 341-344.

Pendleton, J.W., Egti, D.B. and Peters, D.B. 1967. Response of Zea mays to a "Light rich" field environment. Agron. J. 59: 395-397.

Rao, M.V. 1968. Fertiliser needs and plant population requirements of high yielding rice varieties. Symposium on Agronomy of New Crop Varieties, Pantnagar. 1968.

*Ross, Ju. 1962. On theory of albedo of plant canopies. Nauch. Soobshch. Inst. Geologii Geogr. Akad. Nauk. SSR. 13: 151-164.

*Ross, Ju. and Nilson, T. 1966. Spatial orientation of leaves in plant canopy and its determination. Photosynthetic systems with high productivity. ed. A.A. Nichiporovich: 51-58.

Sandhu, A.S. 1964. Effect of row orientation on the growth and yield of Bajra. Ind. J. Agron. 9: 19-32.

*Santhirasegaram. 1962. Thesis. Waite Inst. Univ. of Adelaide. Adelaide.

*Sato, S. 1956. The optimum conditions of climate for rice culture in the warm districts of Japan. Agri. Met. Jap. 12: 24-26.

Sciecz, G. 1974. Solar radiation for wheat plant growth. J. appl. Ecol. 11: 617-636.

Shahi, H.N. and Gill, P.S. 1976. Effect of number of seedlings per hill and spacing on growth and yield of rice. Ind. J. Agron. 21(4): 392-395.

Sharma, K.C. and Singh, M. 1971. Response of dwarf wheats to row direction and row spacing. Ind. J. Agron. 16: 396-400.

Shekhawat, G.S., Sharma, D.C. and Gupta, M.B. 1966. Wheat growth and production in relation to row spacing and direction of sowing. Ind. J. Agron. 11: 62-65.

Shibles, R.M. and Weber, C.R. 1965. Leaf area, solar radiation interception and drymatter production by soybean. Crop Sci. 5(6): 575-579.

Singh, R.P. and Modgal, S.C. 1977. Response of indica rices to nitrogen and plant spacing. Ind. J. Agron. 22(2): 82-86.

*Soga, Y. and Nozaki, M. 1957. Studies on the relation between seasonal changes of carbohydrates accumulated and the ripening at the stage of generation of growth in rice plant. Proc. Crop Sci. Soc. Jap. 26: 105-108.

Sreenivasan, P.S. and Banerjee, J.R. 1973. The influence of rainfall on the yield of rice at Karjat. Agri. Met. 11: 285-292.

Stansel, J.W., Bollich, C.N., Thysell, J.R. and Hall, V.L. 1965. The influence of light intensity and nitrogen fertility on rice yield components. Rice J. 68(4): 34-35, 49.

Subha Rao, K., Venkataraman, S. and Sarkar, R.P. 1976. Evapotranspiration of paddy crop in relation to pan evaporation at Nellore and Canning. Pre - pub. Sci. Report No. 76/12. India Meteorological Department.

*Takeda, T. and Kumara, A. 1957. Proc. Crop. Sci. Soc. Jap. 26(2).

*Tanaka, A. 1958. Studies on the characteristics of the physiological function of leaf of definite position on stem of the rice plant. J. Sci. Soil Manure. Jap. 29: 329-333.

Tanaka, A., Navasero, S.A., Garcia, C.V., Parao, F.T. and Ramirez, E. 1964. Growth habit of the rice plant in the tropics and its effect on nitrogen response. Technical Bulletin-3. International Rice Research Institute, Philippines: 45-47.

Tanaka, A., Kawano, K., and Yamaguchi, J. 1966. Photosynthesis, respiration, and plant type of the tropical rice plant. Int. Rice Res. Inst. Tech. Bull. 7.

Tanaka, T. 1972. Studies on the light curves, curves of carbon assimilation of rice plants - The interrelation among the light - curves, the plant type and the maximizing yield of rice. Bull. Nat. Inst. Agr. Sci. A. 19: 1-100.

Tomar, P.s. and Mathur, O.P. 1966. Time of sowing and seed rate on yield of wheat under canal irrigation in Rajasthan. Ind. J. Agron. 11: 16-69.

*Tsunoda, S. 1959. A developmental analysis of yielding ability in varieties of field crops. I. Jap. J. Breed. 9: 161-168.

*Tsunoda, S. 1964. A developmental analysis of yielding ability in varieties of field crops. Nichon-Gakajitsu - Shinkokai. Maruzen publishing Company, Tokyo: 135.

*Uchijima, Z. 1961. On characteristics of heat balance of water layer under paddy plant cover. Bull. Natl. Inst. Agric. Sci. A. 8: 243-265.

*Udagawa, T. , Ito, A. and Uchijima, Z. 1974. Phytometrical studies of crop canopies. Proc. Crop Sci. Soc. Jap. 43: 180-195.

Vacchani, M.V. and Rao, M.V. 1959. Influence of spacing on plant characters and yield of transplanted rice. Proceedings of seminar Recent Advances in Agronomy and Soil Science and their Application to Increase Crop Production, June 1959, ICAR : 4.

Vacchani, M.V., Upadhya, S.R. and Rao, M.V. 1961. Influence of spacing on plant characters and yield of transplanted rice. Rice News Teller. 9 (2): 15.

Vamadevan, V.K. 1971. Measurement of albedo in the rice field. Idojaras. 3-4 :219-221.

Vanderbilt, V.C., Bauer, M.E. and Silva, T.T. 1979. Prediction of solar irradiance distribution in a wheat canopy using a laser technique. Agri. Met. 20 : 147 - 160.

*Van Ittersun, A. 1971. A calculation of potential rice yields. Netherlands J. Agri. Sci. 19: 10-21.

Venketeswarlu, B., Prasad, V.V.S.S. and Rao, A.V. 1977. Effects of low light intensity on different ~~of low~~ growth phases in rice. Plant and Soil. 47 (1): 837-847.

Venketeswarlu, B. and Sreenivasan, T.C. 1978. Influence of low light intensity on growth and productivity in relation to population pressure and varietal reaction in irrigated rice. Ind. J. Pl. Phy. XXI (2) : 162 - 170.

* Warren Wilson, J. 1959. Analysis of spatial distribution of foliage by two dimensional point quadrats. New Phytol. 58 : 92 - 101.

* Warren Wilson, J. 1963. Estimation of foliage denseness and foliage angle by inclined point quadrats. Aust. J. Bot. 11 (1) : 95-105.

Watson, D.J. and Witis, D.J. 1959. The net assimilation rates of wild and cultivated beets. Ann. Bot. 23 : 431-439.

Yamada, N. 1961. On the relationship between yield and spacing in rice. Agri. and Hort. 36 (1): 13-18, 311-316.

* Yamada, N. 1963. Spacing. Theory and practice of growing rice. Ministry of Agriculture and Forestry, Tokeyo, Japan : 172-182.

Yao, A.V.M. and Shaw, R.H. 1964. Effect of plant population and planting pattern of corn on distribution of net radiation. Agron. J. 56 : 165-169.

* Yin, H.Z. Wang, T.D., Li, Y.Z. Qiu, G.X., Yang, S.Y. and Shen, G.M. 1960. Community structure and light utilisation of rice fields. Sci. Sinica. 9 : 790-811.

Yoshida, S. and Ahn, S.B. 1968. The accumulation process of carbohydrate in rice varieties in relation to their response to nitrogen in the tropics. Soil Sci. Plant Nutr. (Tokyo). 14 : 153-161.

Yoshida, S., Cock, J.H. and Parao, F.T. 1972 Physiological aspects of high yields. Rice ~~Research~~ breeding. International Rice Research Institute, Philippines: 455-469.

Yoshida, S. and Parao, F.T. 1976. Climatic influence on yield and yield components of lowland rice in the tropics. Climate and rice. International Rice Research Institute, Philippines: 471-494.

* Originals not seen.

APPENDICES

APPENDIX I

Analysis of variance

Height of plant on 30th day after planting (cm)

Source	S.S	df	M.S	F
Total	498.02	71	---	---
Block	2.06	2	1.03	.4
S	3.97	1	3.97	1.54
A	1.11	2	.56	.22
S X A	58.26	2	29.13	11.29**
Error (1)	25.75	10	2.58	----
O	87.48	3	29.16	4.42**
S X O	28.43	3	9.48	1.44
A X O	45.33	6	7.56	1.15
S X A X O	8.54	6	1.42	.22
Error (2)	237.09	36	.59	----

** Significant at .01 level.

APPENDIX II

Analysis of variance

Height of plant on 60th day after planting (cm)

Source	S.S	df	M.S	F
Total	769.3	71	----	-----
Block	4.26	2	2.13	.54
S	51.68	1	51.68	13.18**
A	3.25	2	1.63	.42
S X A	21.88	2	10.94	2.79
Error (1)	39.16	10	3.92	----
O	118.32	3	39.44	3.79*
S X O	14.38	3	4.8	.46
A X O	7.54	6	1.3	.13
S X A X O	134.57	6	22.43	2.16
Error (2)	374.26	36	10.4	----

** Significant at .01 level.

* Significant at .05 level.

APPENDIX III

Analysis of variance

Height of plant at the time of harvest. (cm)

Source	S.S	df	M.S	F
Total	1152.58	71	----	----
Block	2.82	2	1.41	.71
S	61.79	1	61.79	31.05**
A	103.13	2	51.57	25.91**
S X A	27.8	2	13.9	6.98*
Error (1)	19.85	10	1.99	----
O	90.22	3	30.07	1.37
S X O	15.78	3	5.26	.23
A X O	8.73	6	1.46	.07
S X A X O	14.33	6	2.39	.11
Error (2)	808.13	36	22.45	----

** Significant at .01 level.

* Significant at .05 level.

APPENDIX IV

Analysis of variance

Number of tillers on 30th day after planting.

Source	S.S	df	M.S	F
Total	290950	71	---	---
Block	12175	2	6087.5	1.85
S	55000	1	55000	16.76**
A	10725	2	5362.5	1.63
S X A	7100	2	3550	1.08
Error (1)	32825	10	3282.5	---
O	61850	3	20616.7	9.65**
S X O	9150	3	3050	1.43
A X O	9375	6	1562.5	.73
S X A X O	15875	6	2645.8	1.24
Error (2)	76875	36	2135.4	---

** Significant at .01 level.

APPENDIX V

Analysis of variance

Number of tillers on 60th day after planting.

Source	S.S	df	M.S	F
Total	625300	71	---	---
Block	1875	2	937.5	1.20
S	178500	1	178500	228.85**
A	38825	2	19412.5	24.88**
S X A	9600	2	4800	6.15*
Error (1)	7800	10	780	---
O	154050	3	51350	16.96**
S X O	61325	3	20441.7	6.75*
A X O	25400	6	4233.3	1.40
S X A X O	38950	6	6491.7	2.14
Error (2)	108975	36	3027.1	--

** Significant at .01 level.

* Significant at .05 level.

APPENDIX VI

Analysis of variance

Number of tillers at the time of harvest.

Source	S.S	df	M.S	F
Total	264400	71	--	---
Block	2775	2	1387.5	2.15
S	59275	1	59275	91.90**
A	100	2	50	.08
S X A	1100	2	550	.85
Error (1)	6450	10	645	---
O	87075	3	29025	13.74**
S X O	1000	3	333.33	.16
A X O	9950	6	1658.33	.78
S X A X O	21050	6	3508.33	1.66
Error (2)	76075	36	2113.19	--

** Significant at .01 level.

APPENDIX VII

Analysis of variance

Leaf area index on 40th day after planting

Source	S.S	df	M.S	F
Total	128.41	71	---	---
Block	.02	2	.01	.5
S	9.81	1	9.81	490.5**
A	7.75	2	3.88	194 **
S X A	3.22	2	1.61	80.5**
Error (1)	.19	10	.02	----
O	100.4	3	33.47	371.89**
S X O	.39	3	.13	1.45
A X O	1.26	6	.21	2.33
S X A X O	2.13	6	.36	4 **
Error (2)	3.24	36	.09	----

** Significant at .01 level

* Significant at .05 level

APPENDIX VIII

Analysis of variance

Leaf area index on 75th day after planting

Source	S.S	df	M.S	F
Total	133.58	71	---	----
Block	.02	2	.01	.09
S	9.9	1	9.9	90 **
A	6.14	2	3.07	27.91**
S X A	3.47	2	1.74	15.82**
Error (1)	1.05	10	.11	----
O	103.91	3	34.64	247.43**
S X O	.04	3	.01	.25
A X O	1.49	6	.25	1.79
S X A X O	2.49	6	.42	3*
Error (2)	5.09	36	.14	-----

** Significant at .01 level.

* Significant at .05 level.

APPENDIX IX

Analysis of variance

Leaf area index on 90th day after planting

Source	S.S	df	M.S	F
Total	85.15	71	---	---
Block	0	2	0	0
S	13.5	1	13.5	6750**
A	1.88	2	.94	470**
S X A	1.19	2	.60	300**
Error (1)	.02	10	.002	---
O	60.17	3	22.06	118**
S X O	1.12	3	.37	2.18
A X O	1.04	6	.17	1
S X A X O	.18	6	.03	.18
Error (2)	6.05	36	.17	----

** Significant at .01 level.

APPENDIX X

Analysis of variance

Leaf area index at the time of harvest

Source	S.S	df	M.S	F
Total	56.45	71	---	---
Block	.01	2	.005	.42
S	.1	1	.1	8.33*
A	.46	2	.23	19.17**
S X A	0	2	0	0
Error (1)	.12	10	.012	----
O	52.46	3	17.49	218.63**
S X O	.08	3	.03	.38
A X O	.15	6	.03	.38
S X A X O	.03	6	.01	.13
Error (2)	3.04	36	.08	-----

** Significant at .01 level

* Significant at .05 level

APPENDIX XI

Analysis of variance

Number of productive tillers

Source	S.S	df	M.S	F
Total	81700	71	--	--
Block	775	2	387.5	.76
S	6800	1	6800	13.40**
A	4900	2	2950	5.81*
S X A	375	2	187.5	.37
Error (1)	5075	10	507.5	---
O	28800	3	9600	13.82**
S X O	4975	3	1658.33	2.39
A X O	2500	6	416.67	.60
S X A X O	2500	6	416.67	.60
Error (2)	25000	36	694.44	---

** Significant at .01 level.

* Significant at .05 level.

APPENDIX XII

Analysis of variance

Length of panicle (cm)

Source	S.S	df	M.S	F
Total	206.85	71	---	---
Block	1.06	2	.53	2.79
S	4.86	1	4.86	25.58**
A	7.59	2	3.80	20 **
S X A	3 .72	2	1.86	9.79**
Error (1)	1.89	10	.19	----
O	103.88	3	34.63	20.49**
S X O	.34	3	.11	.07
A X O	9.46	6	1.58	.94
S X A X O	13.38	6	2.23	1.32
Error (2)	60.67	36	1.69	----

** Significant at .01 level

APPENDIX XIII

Analysis of variance

Number of grains per panicle

Source	S.S	df	M.S	F
Total	11167.49	71	----	---
Block	4.19	2	2.10	2.44
S	4882.37	1	4882.37	5677.17**
A	1666	2	833	968.61**
S X A	862.1	2	431.05	501.22**
Error (1)	8.58	10	.86	---
O	2194.72	3	731.6	28.23**
S X O	144.83	3	48.28	1.86
A X O	195.57	6	32.6	1.26
S X A X O	276.08	6	46.01	1.78
Error (2)	933.05	36	25.92	----

** Significant at .01 level

APPENDIX XIV

Analysis of variance

Thousand grain weight(g)

Source	S.S	df	M.S	F
Total	140.54	71	---	---
Block	2.78	2	1.39	2.44
S	.66	1	.66	1.16
A	.36	2	.18	.32
S X A	34.84	2	17.42	30.56**
Error (1)	5.72	10	.57	---
O	28.01	3	9.34	7.59**
S X O	2.41	3	.8	.65
A X O	13.83	6	2.31	1.88
S X A X O	7.68	6	1.28	1.04
Error (2)	44.25	36	1.23	---

** Significant at .01 level.

APPENDIX XV

Analysis of variance

Grain yield (Kg/ha).

Source	S.S	df	M.S	F
Total	305800	71	---	---
Block	5200	2	2600	2.03
S	10300	1	10300	8.05*
A	3800	2	1900	1.48
S X A	2000	2	1000	.78
Error (1)	12800	10	1280	----
O	92600	3	30866.67	7.46**
S X O	800	3	266.67	.06
A X O	6000	6	1000	.24
S X A X O	3300	6	550	.13
Error (2)	149000	36	4138.89	---

** Significant at .01 level.

* Significant at .05 level.

APPENDIX XVI

Analysis of variance

Straw yield (Kg/ha).

Source	S.S	df	M.S	F
Total	48000	71	---	---
Block	200	2	100	.77
S	4100	1	4100	31.54**
A	6800	2	3400	26.15**
S X A	6200	2	3100	23.85**
Error (1)	1300	10	130	----
O	20100	3	6700	36.55**
S X O	1000	3	333.33	1.82
A X O	700	6	116.67	.64
S X A X O	1000	6	116.67	.91
Error (2)	6600	36	183.33	---

** Significant at .01 level.

APPENDIX XVII

Analysis of variance

Drymatter Production (Kg/ha).

Source	S.S	df	M.S	F
Total	125200	71	--	--
Block	900	2	450	.57
S	10500	1	10500	13.29**
A	14800	2	7400	9.37**
S X A	7800	2	3900	4.94*
Error (1)	7900	10	790	---
O	56500	3	18833.33	33.24**
S X O	800	3	266.67	.47
A X O	1000	6	166.67	.29
S X A X O	4600	6	766.67	1.35
Error (2)	20400	36	566.67	--

** Significant at .01 level.

* Significant at .05 level.

APPENDIX XVIII

Analysis of variance

Grain/Straw ratio

Source	S.S	df	M.S	F
Total	1.99	71	--	--
Block	.016	2	.008	.49
S	.022	1	.022	1.34
A	.138	2	.069	4.21*
S X A	.15	2	.08	4.88*
Error (1)	.164	10	.0164	---
O	.017	3	.006	.154
S X O	.04	3	.013	.333
A X O	.028	6	.005	.128
S X A X O	.018	6	.003	.77
Error (2)	1.4	36	.039	---

* Significant at .05 level.

APPENDIX XIX

Analysis of variance

Nitrogen content (%)

Source	S.S	df	M.S	F
Total	1837.92	71	---	----
Block	34.31	2	17.16	3.18
S	29.70	1	29.70	5.5**
A	0	2	0	0
S X A	59.39	2	29.70	5.5**
Error (1)	53.96	10	5.40	---
O	588.80	3	196.27	13.92**
S X O	148.48	3	49.49	3.51*
A X O	296.97	6	49.50	3.51
S X A X O	118.78	6	19.80	1.40
Error (2)	507.53	36	14.1	---

** Significant at .01 level.

* Significant at .05 level.

Note: Data analysed after Sin^{-1} transformation.

APPENDIX XX

Analysis of variance

Phosphorous content (%)

Source	S.S	df	M.S	F
Total	773.1	71	---	---
Block	.78	2	.39	1.80
S	35.36	1	35.36	162.95**
A	111.02	2	55.51	255.81**
S X A	75.86	2	37.93	174.79**
Error (1)	2.17	10	.217	---
O	479.04	3	159.68	682.39**
S X O	16.92	3	5.64	24.52**
A X O	26.18	6	4.36	18.96**
S X A X O	17.35	6	2.89	12.57**
Error (2)	8.42	36	.23	----

** Significant at .01 level.

Note: Data analysed after $\sin^{-1}$ transformation.

APPENDIX XXI

Analysis of variance

Potassium Content (%)

Source	S.S	df	M.S	F
Total	9987.34	71	---	---
Block	8.78	2	4.39	.70
S	39.52	1	39.52	6.28*
A	564.79	2	282.40	44.90**
S X A	1507.92	2	753.96	119.87**
Error (1)	62.92	10	6.29	---
O	5713.07	3	1904.36	204.77**
S X O	991.77	3	330.59	35.55**
A X O	433.97	6	72.33	7.78**
S X A X O	329.73	6	55.00	5.91**
Error (2)	334.87	36	9.30	---

** Significant at .01 level.

* Significant at .05 level.

Note: Data analysed after Sin^{-1} transformation.

APPENDIX XXII

Analysis of variance

Uptake of nitrogen(Kg/ha)

Source	S.S	df	M.S	F
Total	1930	71	---	---
Block	16	2	8	.83
S	47	1	47	4.90*
A	125	2	62.5	6.51*
S X A	21	2	10.5	1.09
Error (1)	96	10	9.6	---
O	1076	3	358.67	63.61**
S X O	61	3	20.33	3.61*
A X O	92	6	15.33	2.72*
S X A X O	193	6	32.17	5.70**
Error (2)	203	36	5.64	---

** Significant at .01 level

* Significant at .05 level

APPENDIX XXIII

Analysis of variance

Uptake of Phosphorous(Kg/ha)

Source	S.S	df	M.S	F
Total	14825	71	---	---
Block	16	2	8	.39
S	1095	1	1095	53.94
A	1004	2	502	24.73**
S X A	992	2	496	24.43**
Error (1)	203	10	20.3	---
O	10162	3	3387.33	1017.22**
S X O	261	3	87	26.13**
A X O	222	6	37	11.11**
S X A X O	750	6	125	37.54**
Error (2)	120	36	3.33	---

** Significant at .01 level.

APPENDIX XXIV

Analysis of variance

Uptake of Potassium (Kg/ha)

Source	S.S	df	M.S	F
Total	8555	71	---	---
Block	27	2	13.5	1.39
S	4	1	4	.41
A	276	2	138	14.23**
S X A	1390	2	695	71.65**
Error (1)	97	10	9.7	---
O	5461	3	1830.33	2056.55**
S X O	65	3	21.67	24.35**
A X O	238	6	39.67	44.57**
S X A X O	935	6	155.83	175.09**
Error (2)	32	36	.89	----

** Significant at .01 level.

INFLUENCE OF CROP GEOMETRY ON THE GROWTH AND YIELD OF RICE VARIETY JAYA

By

K. E. USHA

ABSTRACT OF A THESIS

submitted in partial fulfilment of
the requirement for the degree

Master of Science (Agronomy)

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur
1985

ABSTRACT

Influence of crop geometry on the growth and yield of rice variety 'Jaya'.

An experiment was conducted in the Regional Agricultural Research Station, Pattambi during the second crop season of 1983 to study the influence of crop geometry on the growth and yield of rice variety 'Jaya'. The experiment was laid out in split plot with three replications. The treatments consisted of six treatment combinations of two levels of spacing between plants (20 X 15 cm, 20 X 10 cm) and three levels of spacing between alleys (80 cm, 160 cm and 240 cm apart) in the main plot and four levels of crop orientation (North-South, East-West, diagonal planting North East - South West and diagonal planting North West - South East) in the sub plot.

Observations on weather factors such as temperature, relative humidity, rainfall, sunshine hours, wind velocity and evaporation were recorded daily. Crop growth characters like height, number of tillers, leaf area index were recorded at different stages of development of the crop and yield components like number of productive tillers, length of panicle, and yield of grain and straw were noted during the harvest.

The day time variation of albedo was also measured at frequent intervals.

N-S oriented crop was significantly superior to others with regard to crop growth characters as well as yield components. Height, number of tillers, number of productive tillers, length of panicle and number of grains per panicle were influenced by the 20 X 15 cm spacing while the 20 X 10 cm spacing showed the maximum drymatter production, maximum thousand grain weight and the highest value of grain and straw yields. The grain yield was not significantly influenced by the alley treatments.

It was found that proper spacing and orientation had significant effect on overall growth and yield of the crop. Highest grain yield was recorded in plots with N-S orientation and with 20 X 10 cm spacing. The best performance is attributed to more effective utilisation of solar radiation with the uniform exposure of plants to sunlight.

The albedo measurements were also higher over the closely spaced and N-S oriented plots indicating the better growth and performance of the crop.

Results of the present investigation indicate that rice in Kerala during the second crop season can be grown most successfully if planted at a spacing of 20 X 10 cm and oriented in N-S direction.