EFFECT OF DEFOLIATION AT PANICLE EMERGENCE AND ANTHESIS ON GRAIN YIELD IN RICE

(Oryza sativa L.)

By

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THESIS

SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENT FOR THE DEGREE

MASTER OF SCIENCE IN AGRICULTURE

(AGRICULTURAL BOTANY)

FACULTY OF AGRICULTURE

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF AGRICULTURAL BOTANY

COLLEGE OF AGRICULTURE, VELLAYANI

TRIVANDRUM

1978

DECLARATION

I hereby declare that this thesis entitled "Effect of defoliation at panicle emergence and anthesis on grain yield in rice (*Oryza sativa* L.)" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any University or Society.

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CERTIFICATE

Certified that this thesis, entitled "Effect of defoliation at panicle emergence and anthesis on grain yield in rice (Oryza sativa L.)" is a record of research work done independently by Shri. SYED MOSHIN IBRAHIM, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

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ACKNOWLEDGEMENTS

I express my deep sense of gratitude and indebtedness to Shri. N. Gopinathan Nair, Chairman, Advisory Committee, Associate Professor of Agricultural Botany, College of Agriculture, Vellayani for suggesting the problem, for his sustained and keen interest, constructive criticisms, valuable guidance, timely suggestions and constant encouragement evinced at every stage of the investigation and in the preparation of this thesis.

I am thankful to Shri. A.T.Abraham, Associate Professor of Agricultural Botany and Dr. V.Gopinathan Nair, Associate Professor of Agricultural Botany, College of Agriculture, Vellayani, for providing practical suggestions in this investigations.

I am deeply indebted to Prof. E.J. Thomas, Head of the Department of Agricultural Statistics for the help and assistance rendered by him during the course of analysis of data and interpretation of results.

I am thankful to Dr. (Mrs.) Mary K. George, Professor of Agricultural Botany for the encouragement and suggestions given by her during the course of research.

(SYED MOSHIN IBRAHIM)

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INTRODUCTION

INTRODUCTION

Nine-tenths of the world's rice is produced and consumed in the Far East. A review of the trends in area, production, and yield of rice from 1934 to 1960 shows that the increased production in the major rice producing countries of tropical Asia, more or less kept pace with population increase, but the change in yields has been negligible. Apparently, rice breeding had no significant impact on yields during this period. At a symposium on the mineral nutrition of rice plants in 1964, what rice scientists call 'plant type' received considerable attention from physiologists and breeders. The concept of the plant type had tremendous impact on rice breeding as it formed the basis for evolving high yielding varieties of rice.

The physiological processes involved in grain production such as vegetative growth, formation of storage organs and grain filling also have been subjected to extensive investigations. It has been found that most of the carbohydrates required for filling the grain are derived from photosynthesis taking place after ear emergence. The lamina is the only significant organ, though under certain conditions other organs like leaf sheaths, peduncles, and ears are important contributors of photosynthetic products especially during the grain filling period.

Defoliation studies conducted by Klinck and Sim (1976) in oats indicated that the grain yield decreased more with leaf lamina removal at panicle emergence than at anthesis. The period between panicle emergence and anthesis though only 5 days in their work, appeared to be an important one in terms of plant response to leaf damage. They found that yield reductions resulting from defoliation at panicle emergence were almost double those from the same treatment at the later stage. It was pointed out that mechanical damage to the leaves by hail, insects or other agents or severe leaf disease infection at the early heading stage could have drastic effects on grain yield.

In rice, as in oats, there is a short period between panicle emergence and anthesis. A number of diseases and pests are known to cause severe leaf damage in rice, at this stage. Some of the diseases which are important in this respect are blast, helminthosporiose, bacterial blight, sheath blight, and sheath rot. The damage caused to rice leaves by insect pests like noctuid cut worms, army worms, leaf folders, leaf rollers, and grass-hoppers is well documented.

The present study was undertaken to find out, whether the period between panicle emergence and anthesis in rice is important in terms of plant response to leaf damage, as recorded in oats.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Since Tsunoda's (1959 a, 1959 b, 1960, 1962, 1964) pioneering work, in which he compared high and low yielding rice varieties, considerable attention has been paid to the relationship between morphological characters and yielding ability. Donald (1968) described the morphological requirement for wheat ideotype. The morphological characters of leaf, culm, tiller and panicle associated with high yielding potential of rice varieties had been described by Yoshida (1972).

Understanding the physiological processes involved in grain production such as vegetative growth, formation of storage organs and grain filling helps determine the best combination of the above three factors and suggest the improvements that can be made to achieve a further increase in grain yield under a given condition. The association between the relative photosynthetic activity of different plant structures and grain productivity in cereal crops, particularly wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) has been the subject of many investigations. Extensive reviews on this aspect had been prepared by Yoshida (1972), Austin and Jones (1974) and Thorne (1974).

The leaf lamina is the only significant organ of photosynthesis (Zelitch, 1971), though under certain conditions other organs like leaf sheaths, peduncles, and ears are important contributors of photosynthetic products especially during the grain filling period. According to Yoshida (1972) thick leaves are associated with more erect habits permitting higher photosynthetic rate per unit area. Short and small leaves are associated with more erect habits and help in the even distribution of leaves in a canopy. Erect leaves increase 'Sun lit' leaf surface area, thereby permitting more even distribution of incidental light. The contribution of leaves to grain filling in cereals has been studied in great detail and it was found that varieties differ markedly in leaf and other characters.

Leaf area duration

In physiological studies of the evolution of wheat it has been shown that modern cultivated varieties have been selected for larger leaf area and larger grain size. A high yielding semi dwarf wheat variety, has a high leaf photosynthetic rate, but shows a low relative growth rate because of low leaf area ratio, (Bingham, 1967). Venkateswarlu (1976) working in paddy reported that the leaf determined not only the degree of the plant's performance but also conditioned the level of unfilled spikelets.

Venkateswarlu and Maddulety (1976) observed that increased grain number in paddy could come mainly through two ways; (i) by increased number of panicles, and (ii) through the supply of more photosynthates to the spikelets. In any case, the realization is dependent on the effective functional capacity of the leaf only.

The leaf area duration of a crop is a measure of its ability to produce leaf area on unit area of land throughout its life and hence of its whole opportunity for assimilation (Watson, 1952). As early as 1929, Boonstra observed that four varieties of oats differed in the length of life of corresponding leaves and found some evidence of an association of long life with high yield. Williams and Rijven (1965) suggested that the varietal differences in grain yield are determined by the combined effects of duration of photosynthetic activity, photosynthetic rate and potentiality for growth of the grain itself. The amount of photosynthesis in wheat depends first on the size and duration of the photosynthetic system and secondly on its efficiency (Welbank <u>et al</u>. , 1966). Reddy and Pyare lal (1976) reported that the leaf area duration was positively correlated with grain yield in triticale and wheat varieties.

Photosynthetic efficiency is found to decline with the age of the leaf. Saeki (1959) observed that each leaf showed a maximum rate of photosynthesis before it was fully expanded followed by a progressive decline in Phaseolus viridissimus and Fagophyrum esculentum. Hopkinson (1964) found that each leaf in cucumber showed a maximum rate of photosynthesis before it was fully expanded followed by a progressive decline. Jewiss and Woledge (1967) noticed the progressive decline in apparent photosynthesis with increasing age of leaf in tall fescur and concluded that the fall in apparent photosynthesis with leaf age was due to a fall in the rate of real photosynthesis.

The reports on the influence of the age of the leaf on transport of assimilates are conflicting. Mokronosov and Bubenshchikova (1961) observed that the movement of assimilates into the conducting vessels of potato is greater in young than in old fully expanded leaves. Thrower (1962) on the other hand, reported that in soybean very young leaves obtain carbohydrates required for their growth from older leaves. Evidence presented by Milthorope (1966) showed that until a leaf is almost mature there will be little export of carbohydrates.

Leaf orientation

Watson and Witts (1959) found that a cultivated variety of sugar beet characterized by erect leaves produced dry matter more rapidly than three wild species with more prostrate leaves and the smaller yield of the wild plants was attributed to less uniform distribution of light over their leaves. According to Monteith (1965) in sugar beet, sugarcane, Kale and sub-terranean clover with a leaf area index of above 5, light utilisation is better when the leaves are erect in comparison with leaves which are prostrate. Buttrose and May (1965) emphasised the importance of the leaves in contributing assimilates to the grain of cereals varies with light conditions. Duncan *et al.* (1967) predicted from mathematical models that leaf angles less than 19^{o} might increase efficiency even more particularly when a high LAI is present. The semi dwarf lines in rice that had more erect flag leaves had higher grain yields, and this trait showed the largest direct effect on grain yield (Chang and Tagumpay, 1970). Leaf angle has been closely correlated with nitrogen response in rice, barley and wheat (Yoshida, 1972).

Chlorophyll content

According to Brougham (1960), production of dry matter by pasture and crop species is ultimately limited by the amount of chlorophyll. Hunt and Cooper (1967) found that the differences among temperate grass species in chlorophyll per unit leaf area were closely associated with the rate of dry matter accumulation. Salisbury and Ross (1969) observed that there is little correlation between chlorophyll content and photosynthesis. The results obtained by Reddy and Pyare lal (1976) also showed poor correlation between chlorophyll content at different stages and grain yield in both triticale and wheat varieties, whereas Palit (1976) noted that irrespective of stages rice varieties showed high chlorophyll content per unit area of land and this was correlated with their higher grain yield.

Grain filling period

Davidson (1965) stated that the photosynthesis taking place in the leaf area prior to ear emergence excerts a major influence on the potential grain size and ultimately influence the grain yield in wheat, whereas leaf area following ear emergence would be of major importance in grain filling. Thorne (1965) suggested that after anthesis the dry matter of the wheat grain was largely derived from the products of Co_2 assimilation in the ear, the flag leaf with its sheath and peduncle. Welbank et al. (1966) reported that wheat varieties had grain yields nearly proportional to their leaf area durations, primarily flag leaf area from anthesis rather than panicle emergence during grain development. Murata (1964), De Datta and Zarate (1970), reported that the yield of rice has been correlated with solar radiation from 10 to 15 days before flowering until harvest, and it was suggested that the grain yield is related to the amount of photosynthesis during these periods. Yoshida <u>et al</u>. (1972 b) reported that in paddy the grain yield and LAI at heading are closely correlated. According to Reddy and Pyare lal (1976) the dry matter in wheat after heading was better associated with grain yield than the dry matter before heading.

<u>Leaf photosynthesis</u>

Sixty per cent of the dry matter in the wheat grain is derived from the photosynthesis in the flag leaf laminae, sheath and peduncle and 17 per cent from the parts of shoot below the base of the flag leaf sheath (Boonstra, 1937). Tanner and Daynard (1967) reported the great potential contribution of the middle leaves of a corn canopy to grain yield. According to Klinck and Sim (1976) in wheat the contribution of the leaf immediately below the flag leaf to grain filling was more than one third of that of the flag leaf.

Current photosynthetic contribution was found to be the major determinant of yield in rice, though the late duration varieties draw comparatively more photosynthates from the reserve carbohydrates (Venkateswarlu, 1977).

The upper three leaves in rice export their assimilation products to the grains during the ripening period (Tanaka, 1958 b). Wardlaw (1968) found that the contribution of the lower leaves in rice is more important than that in the other cereals. Tripathi and Purohit (1971) suggested that the first 3-4 leaves at the top are most important in dry matter production in rice. It was pointed out by Yoshida (1972) that the second (penultimate) and third leaves are relatively important in rice.

Sinks and sources

Bonnemain (1965) pointed out that the lower leaves act as the source of assimilates for roots, whereas the upper leaves perform this function for the shoot apex, and leaves in an intermediate position may supply assimilates in either or both directions. Lupton (1966) reported that in wheat the translocation of carbohydrates from the glumes and flag leaf was almost entirely towards the grain whereas the translocation from the 2nd or the 3rd leaves was partly towards the grain and partly downwards with evidence of varietal differences.

Ear photosynthesis

Ear photosynthesis accounted for 34 per cent of the grain yield in cereals (Boonstra, 1937). Archbold (1942) emphasised the importance of photosynthesis in the ear as a factor determining yield in barley. Removing awns of barley decreased grain weight by 10 per cent (Watson, 1952). According to Buttrose (1962) ear photosynthesis in cereals contributed 50 per cent to grain yield. Photosynthetic activity of the inflorescence of cereals contributes 30 per cent or more towards grain dry weight at harvest (Thorne and Gillian, 1963). Jennings and Shibles (1968) found the contribution of photosynthates by spike in oats towards grain filling was more than that of other plant parts after ear emergence. Contribution of ear photosynthesis to the grain ranged from 10 to 49 per cent for wheat, and 26 to 76 per cent for barley. In rice and corn compared with the leaf blades, net photosynthesis of ear and leaf sheath was very low. The contribution of ear photosynthesis to the grain ranged from 8 to 23 per cent for rice (Yoshida, 1972).

Defoliation studies

To estimate the over all contribution of different plant parts to grain production, various techniques have been devised: ear and leaf shading, leaf removal, kernel competition, and the short or long term measurement of CO_2 exchange rate. The combination of the first two techniques has been most extensively used because they are the easiest to use. Such estimation, however, is subject to large variation due to such sources as the amount of the stored carbohydrate, timing of defoliation treatment, and panicle size. Therefore, a relatively high yield for defoliated plant does not necessarily mean that the leaves contribute little to grain filling. On the other hand, a low yield indicates that photosynthesis by leaves contributes much to the grain yield (Yoshida, 1972).

Miller et al. (1948) found in eight varieties of wheat a mean reduction in yield of only 10.5 per cent for complete defoliation at the ligule, one week after anthesis and 4.8 per cent yield reduction when half of every leaf was removed. Shading and defoliation experiment Quinlan and Sagar (1962) showed that the upper leaves, stem, and ear were responsible for supporting 80 per cent to 90 per cent of the grain growth in wheat. Lucas and Asana (1968) reported that removal of the fifth and sixth leaves reduced the grain yield in wheat by about 5 per cent. They found that reduction in yield due to defoliation was the result of reductions in both grain number and 1000 grain weight. Bagga and Asana (1972) observed that the excision of the laminae of the fifth (penultimate) and sixth (flag) leaves after anthesis on the shoots of 3 cultivars of wheat (*Triticum aestivum*) depressed the grain yield through grain number per ear. The results obtained by Walpole and Morgan (1974) showed that severe defoliations reduced grain weight in wheat. Klinck and Sim (1976) conducted leaf defoliation studies in oats and found that yield reductions resulting from defoliation at panicle emergence were almost double those from similar treatments at the later stage.

Defoliation studies in rice

Takeda and Maruta (1956) found that the removal of the second to fourth leaves in rice decreased the grain yield much more than removing the flag leaf and they also observed that the complete defoliation at flowering decreased the grain weight to 55 per cent. Matsushima (1957) reported that complete defoliation in rice at flowering decreased the ripening percentage to 36 per cent of the control. According to Owen (1968) the complete defoliation in paddy at flowering decreased the grain weight 81 to 88 per cent. The removal of half the flag leaf at panicle emergence reduced the grain yield in paddy by 14 per cent, grain number by 5 per cent, and increased sterility by 9 per cent whereas complete removal of flag leaf reduced grain yield by 19 per cent, grain number by 13 per cent, and increased sterility by 18.2 per cent (Tripathi and Purohit, 1971). Sikder and Das Gupta (1976) conducted defoliation studies at panicle emergence in paddy and found 20.9 per cent contribution from the top two leaves to grain filling.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was conducted in the Division of Agricultural Botany, College of Agriculture, Vellayani, during the year 1977-78.

A. MATERIALS

Materials used in the present investigation consisted of three varieties of rice (*Oryza sativa* L.):

1. Jyothi, a short duration dwarf improved variety of about 105 days duration. The seeds were supplied by the Instructional Farm, College of Agriculture, Vellayani.
2. Ptb.10, a short duration tall improved local variety of about 100 days duration. The seeds were obtained from Central Rice Research Station, Pattambi.
3. Jaya, a medium duration dwarf improved variety of about 125 days duration. The seed material was supplied by the Government Seed Farm, Ulloor.

B. METHODS

Defoliation was adopted as the method for assessing the contribution of leaves to grain filling.

A split plot experiment was laid out in Randomised Block Design with three replications and with three varieties and two stages as major treatments and defoliations as minor

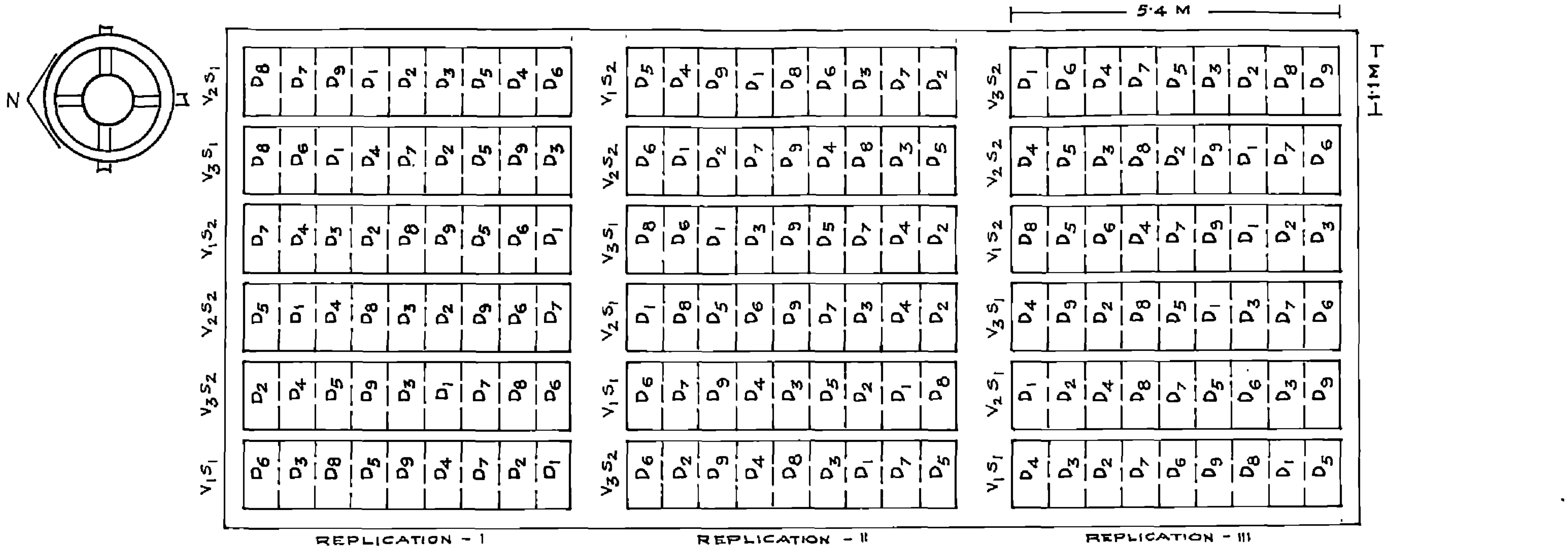
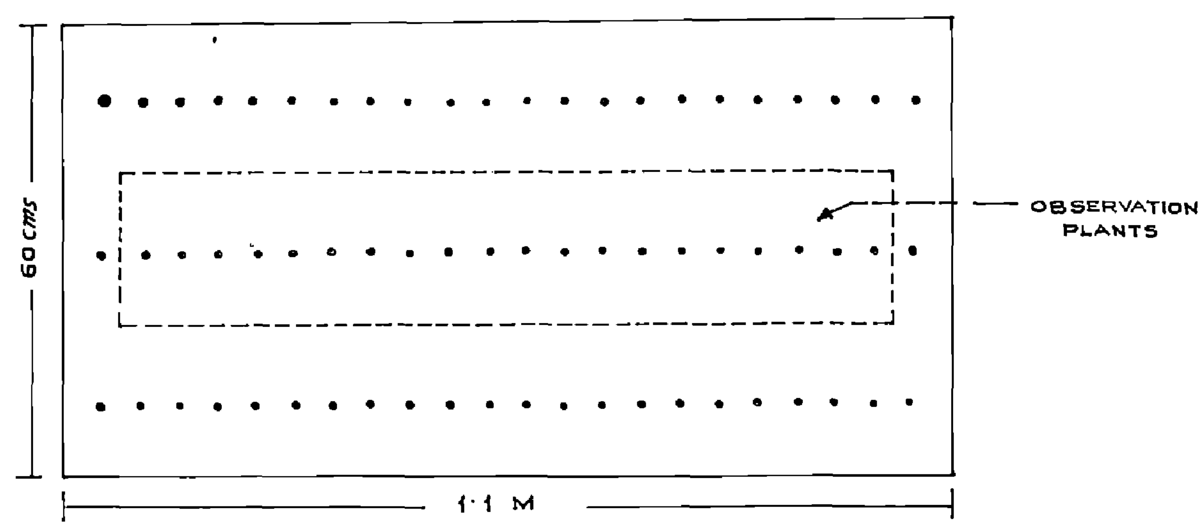


FIG. 1. LAY OUT - SPLIT PLOT EXPERIMENT IN RANDOMISED BLOCK DESIGN



SINGLE SUB-PLOT (ENLARGED)

treatments (Fig.I), the details of which are given below:

Block size	-	10.6 m x 6.9 m
Main plot size	-	5.4 m x 1.1 m
Sub plot size	-	1.1 m x 60 cm

A sub plot consisted of 3 gross rows, each containing 22 plants. Each treatment comprised of 20 plants in the central row, bordered on each side by an untreated guard row.

Major treatments

The main plots comprised of six combinations of three varieties and two stages of development at which defoliation was effected.

Varieties

Jyothi	-	V_1
Ptb.10	-	V_2
Jaya	-	V_3

Stages of development

1. Panicle emergence (Tip emergence) - S_1
2. Anthesis - Eight days after panicle emergence (mid anthesis) - S_2

Combinations of major treatments

1. Defoliation at panicle emergence in Jyothi - V_1S_1
2. Defoliation at anthesis in Jyothi - V_1S_2

3. Defoliation at panicle emergence in Ptb.10 - V_2S_1

4. Defoliation at anthesis in Ptb.10 - V_2S_2

5. Defoliation at panicle emergence in Jaya - V_3S_1

6. Defoliation at anthesis in Jaya - V_3S_2

Minor treatments (Defoliation treatments)

D1 - No defoliation (D + Control)

D2 - Defoliation of flag leaf only (F)

D3 - Defoliation of penultimate leaf only (P)

D4 - Defoliation of flag leaf and penultimate leaf (F + P)

D5 - Defoliation of the third leaf from the top (P')

D6 - Defoliation of flag leaf and the third leaf (F + P')

D7 - Defoliation of penultimate leaf and the third leaf (P + P')

D8 - Defoliation of flag leaf, penultimate leaf and the third leaf (F + P + P')

D9 - Defoliation of all leaves (D-)

Functional leaves

Jaya had five functional leaves and Jyothi and Ptb.10 only four functional leaves, each at panicle emergence. Except when completely defoliated Jaya had an additional leaf in all treatments when compared with Jyothi and Ptb.10.

Uniform sized seeds were hand sown on 13th April 1977, with a spacing of 20 cm between rows, and 5 cm within rows at the rate of 3 seeds per hole. The population was reduced to one plant per hole ten days after sowing. To ensure uniformity, all plants were reduced to the main culm by carefully removing new tillers, as and when they appeared, without damaging the main plant.

Manuring, irrigation and plant protection were adopted according to standard practices to ensure healthy growth of plants.

Observations

Observations on the following aspects were recorded.

1. Leaf area of each functional leaf
2. Leaf angle (leaf openess) of each leaf at panicle emergence
3. Chlorophyll content of leaves
4. Number of filled grains per plant
5. Number of unfilled grains per plant
6. 1000 grain weight in each treatment (dry weight)
7. Total yield per plant (dry weight of filled grains and partially filled grains and chaff)

1. Leaf area determination

A set of ten leaves in each category was removed from border plants. Outline of each leaf was traced on graph paper and the actual leaf area was found out. Care was taken to avoid folding of the leaves while handling them. The leaves were then dried to constant weight in an air oven at 100°C to 105°C and dry weight of each leaf was recorded. A linear regression equation was developed for each leaf from its actual leaf area and dry weight, to obtain the leaf area.

Variety	Stage of defoliation	Leaf lamina	Regression equation
Jyothi	Panicle emergence	Flag leaf	y=0.0891x + 12.4695
		Penultimate leaf	y=0.104x + 12.1320
		Third leaf	y=0.1089x + 13.2530
		Fourth leaf	y=0.0.916x + 17.1766
	Anthesis	Flag leaf	y=0.0939x + 17.9608
		Penultimate leaf	y=0.0966x + 16.9033
		Third leaf	y=0.0703x + 21.4142
		Fourth leaf	y=0.0392x + 25.5756
Ptb.10	Panicle emergence	Flag leaf	y=0.1516x + 6.4966
		Penultimate leaf	y=0.0766x + 19.5700
		Third leaf	y=0.0705x + 22.9733
		Fourth leaf	y=0.0669x + 28.0133
	Anthesis	Flag leaf	y=0.1008x + 24.0507
		Penultimate leaf	y=0.1035x + 19.6214
		Third leaf	y=0.0972x + 18.1277
		Fourth leaf	y=0.08x + 26.6300
Jaya	Panicle emergence	Flag leaf	y=0.095x + 7.3100
		Penultimate leaf	y=0.1087x + 12.7850
		Third leaf	y=0.104x + 12.4278
		Fourth leaf	y=0.0825x + 25.2500
		Fifth leaf	y=0.1007x + 22.1984
	Anthesis	Flag leaf	y=0.091x + 16.4469
		Penultimate leaf	y=0.101x + 19.0342
		Third leaf	y=0.0927x + 18.6565
		Fourth leaf	y=0;0.101x +26.2050
		Fifth leaf	y=0.0855x + 26.3884

2. Measurement of leaf angle (Leaf openess)

The method followed by Yoshida et al. (1969) was adopted.

Leaf angles were measured in ten plants of each variety, at panicle emergency and their mean values were recorded. A vertical board covered with paper was placed behind the main culm, which acted as the vertical axis. With the leaves drooping normally from the axis, the positions of the tip and collar of each leaf were marked on the paper. A line between the two points were drawn and the angle between the line and the vertical axis was measured with a protractor. The leaf angle was expressed as the angle of inclination from the vertical line.

3. Determination of chlorophyll content

The chlorophyll content of the different leaves at panicle emergence and anthesis were estimated by following the procedure adopted by Arnon (1959).

After recording the fresh weight of the leaf 1 gm of fresh leaf tissue was taken and homogenised with 20 ml of 80% acetone, and centrifuged at 3000 ppm for 5 minutes. Supernatant was separated and 10 ml of 80% acetone was added to the pellet and once again centrifuged. This was repeated till the pellet became white. All the supernatant was pooled and made to a final volume of 50 ml. The Optical Density (OD) of the same was read at 645 $m\mu$ and 663 $m\mu$ and the chlorophyll content was calculated as per the formula:

$$\text{Chlorophyll content (mg/ml)} = (0.0202 \times \text{OD. } 645) + (0.00802 \times \text{OD. } 663)$$

Total chlorophyll content in the different leaves were then arrived at.

4. Separation of filled grains and chaff

The procedure followed by Venkateswarlu (1976) was adopted for this purpose.

The grains were put in sodium chloride solution having a specific gravity of 1.06 and the grains which submerged were considered to be fully filled grains. The rest of the grains which floated were collected and manually separated as partially filled grains, and chaff. The grains among the floating ones that touched hard to the finger were taken as partially filled grains and the rest as chaff. The partially filled grains were added to fully filled grains to obtain filled grains. Filled grains and chaff were dried in an oven for 48 hours at 100°C to 105°C and their dry weights recorded. 1000 grain weight was found out from the total dry weight of filled grains and the number of filled grains.

5. Interaction effects

The interaction effects in defoliation treatments were analysed by adopting Yate's method (Kempthorne, 1952).

6. Analysis of data

The data obtained were tabulated and analysed.

RESULTS

RESULTS

The results of this study are presented in this chapter.

LEAF AREA

The analysis of variance table reveals that the leaf area defoliated differed significantly between varieties and stages (Appendix I).

As shown in the table I A maximum functional leaf area was met with in Jaya, which had an additional functional leaf, when compared with Jyothi and Ptb.10, having four functional leaves each. Jaya had a total leaf area of 175.1 sq.cm at panicle emergence, and 183.74 sq.cm at anthesis. It was followed by Ptb.10 with a leaf area of 152.86 sq.cm at panicle emergence, and 159.09 sq.cm at anthesis and its leaf area was considerably higher than that of Jyothi which had a leaf area of 106.4 sq.cm at panicle emergence and 113.87 sq.cm at anthesis. The increase in leaf area of flag leaf after panicle emergence was more striking than that of penultimate leaf. Leaf area of the lower leaves did not register notable increases after panicle emergence. Ptb.10 had the largest flag leaf and Jyothi had the smallest flag leaf at both panicle emergence and anthesis. In all the varieties, the area of the different leaves progressively

Table I A. Mean leaf area of different leaves at panicle emergence and anthesis (in sq.cm).

Leaf	Jyothi		Ptb.10		Jaya	
	Panicle emer-gence	Anthesis	Panicle emer-gence	Anthesis	Panicle emer-gence	Anthesis
Flag leaf	22.25	25.90	32.30	38.18	25.52	30.13
Penultimate leaf	24.81	26.90	36.51	38.38	33.78	35.06
Third leaf	29.97	30.77	42.32	40.63	36.37	38.00
Fourth leaf	29.37	30.30	41.73	41.90	39.81	39.99
Fifth leaf	*	*	*	*	39.62	40.56
Total leaf area	106.40	113.87	152.86	159.09	175.10	183.74

* Non functional

Table I B. Percentage reduction in leaf area due to defoliation treatments

Lead removed	V_1 S_1	V_1 S_2	V_1 Mean of S_1 & S_2	V_2 S_1	V_2 S_2	V_2 Mean of S_1 & S_2	V_3 S_1	V_3 S_2	V_3 Mean of S_1 & S_2
D+	0	0	0	0	0	0	0	0	0
F	20.91	22.82	21.86	21.13	24.00	22.56	14.57	16.40	15.48
P	23.41	23.62	23.51	23.89	24.12	24.00	19.29	19.08	19.18
F+P	44.23	46.37	45.30	45.02	48.12	46.57	33.87	35.48	34.67
P'	28.17	27.02	27.59	27.69	25.54	26.61	20.77	20.68	20.72
F+P'	49.08	49.77	49.42	48.82	49.54	49.18	35.35	37.08	36.21
P+P'	51.48	50.65	51.06	51.57	49.66	50.61	40.06	39.76	39.91
F+P+P'	72.40	73.39	72.89	72.70	73.66	73.18	54.64	56.16	55.40
D-	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
C.D.	0.15	0.14		0.11	0.10		0.09	0.08	

Table I C. Mean leaf area (in sq.cm) of two stages.

Leaf	Jyothi	Ptb.10	Jaya
Flag leaf	24.07	35.24	27.82
Penultimate leaf	25.85	37.44	34.42
Third leaf	30.37	41.34	37.18
Fourth leaf	29.83	41.81	39.90
Fifth leaf	*	*	40.09
Total leaf area	110.13	155.97	179.42

* Nonfunctional

Table I D. Mean leaf area (in sq.cm) of all varieties.

Leaf	Panicle emergence	Anthesis
Flag leaf	26.69	31.40
Penultimate leaf	31.70	33.44
Third leaf	36.22	36.46
Fourth leaf	36.97	37.39
Total leaf area	144.78	152.23

decreased from the lower most leaf to the upper most leaf viz., the flag leaf.

<u>Leaf area reduction due to defoliation</u>

The percentage of reduction in leaf area due to different defoliation treatments is presented in table I B. In all the varieties leaf area defoliated differed significantly between treatments in both stages. The percentage of leaf area lost on the removal of flag leaf, penultimate leaf and the third leaf were 72.89 in Jyothi and 73.18 in Ptb.10 and 55.4 in Jaya. Excision of two leaves in combination reduced leaf area from 45.3 to 51.06 per cent in Jyothi, from 48.12 to 49.66 per cent in Ptb.10 and 34.67 to 39.91 per cent in Jaya. The flag leaf removal resulted in the least reduction in leaf area in all varieties.

<u>Mean leaf area of two stages</u>

The results (Table I C) show that Jaya had the maximum functional leaf area with an area of 179.42 sq.cm, followed by Ptb.10 with 155.97 sq.cm and Jyothi 110.13 sq.cm. Among varieties Ptb.10 recorded the highest leaf area for individual leaves. It was followed by Jaya and Jyothi respectively.

<u>Mean leaf area of all varieties</u>

It is seen from table I D that the flag leaf and the penultimate leaf recorded increases in area after panicle

Table II. Leaf angle at panicle emergence.

Variety	Leaf	Angle of inclination
Jaya	Flag leaf	8°
	Penultimate leaf	9°
	Third leaf	11°
	Fourth leaf	13°
	Fifth leaf	18°
Jyothi	Flag leaf	10°
	Penultimate leaf	21°
	Third leaf	17°
	Fourth leaf	32°
Ptb.10	Flag leaf	84°
	Penultimate leaf	71°
	Third leaf	55°
	Fourth leaf	68°

Table III. Chlorophyll content

Variety	Stage	Leaf	Chlorophyll in mg per gm of fresh leaf	Total chlorophyll in mg per leaf
Jaya	Panicle emergence	Flag leaf	2.199	0.880
		Penultimate leaf	2.173	1.096
		Third leaf	1.766	0.927
		Fourth leaf	1.434	0.609
		Fifth leaf	1.390	0.586
	Anthesis	Flag leaf	2.892	1.446
		Penultimate leaf	2.004	1.102
		Third leaf	1.562	0.859
		Fourth leaf	1.231	0.492
		Fifth leaf	1.189	0.484
Jyothi	Panicle emergence	Flag leaf	2.050	0.854
		Penultimate leaf	2.022	1.104
		Third leaf	1.658	1.006
		Fourth leaf	1.322	0.739
	Anthesis	Flag leaf	2.350	0.902
		Penultimate leaf	2.017	1.122
		Third leaf	1.512	0.604
		Fourth leaf	1.081	0.422

Table continued...

Table III continued

Variety	Stage	Leaf	Chlorophyll in mg per gm of fresh leaf	Total chlorophyll in mg per leaf
Ptb.10	Panicle emergence	Flag leaf	2.010	0.854
		Penultimate leaf	1.920	1.104
		Third leaf	1.610	1.006
		Fourth leaf	1.477	0.739
	Anthesis	Flag leaf	2.280	1.083
		Penultimate leaf	1.908	1.149
		Third leaf	1.325	0.828
		Fourth leaf	1.317	0.724

emergence. The growth of the flag leaf was more marked than that of the penultimate leaf.

LEAF ANGLE

The average leaf angles of various leaves at panicle emergence are presented in table II. It reveals the vertical orientation of the leaves of Jaya. The leaves of Ptb.10 were drooping and produced a wide angle. Jyothi possessed erect leaves though they made a wider angle than Jaya. The flag leaves of Jaya and Jyothi were more erect than their lower leaves. In contrast the flag leaf in Ptb.10 made the largest angle when compared with the lower leaves.

CHLOROPHYLL CONTENT

The chlorophyll content per gram of fresh weight of leaf (Table III) was found to be the highest in Jaya, followed by Jyothi and Ptb.10, respectively. However the chlorophyll content per leaf differed between varieties and leaves due to differences in leaf area. Chlorophyll content in the flag leaf registered an increase after panicle emergence. In all the other leaves chlorophyll content was found to decrease after panicle emergence. Flag leaf registered the highest chlorophyll content per gram of leaf and the chlorophyll contents in different leaves were found to vary in the following order, viz., flag leaf > penultimate leaf > third leaf > fourth leaf > fifth leaf (Jaya only).

Table IV A. Percentage reduction in yield

Treatment	V_1		V_2		V_3	
	S_1	S_2	S_1	S_2	S_1	S_2
D+	0	0	0	0	0	0
F	13.76	8.32	22.32	11.28	17.24	9.20
P	14.30	9.61	18.25	11.40	16.61	8.16
F+P	26.22	15.55	28.25	15.41	25.09	16.98
P'	9.77	5.94	6.05	3.26	13.00	5.12
F+P'	21.79	12.96	23.83	15.91	24.46	13.28
P+P'	27.03	16.95	30.01	16.17	27.62	16.32
F+P+P'	35.65	19.98	35.31	24.69	35.92	21.92
D-	39.73	22.35	39.60	26.57	37.55	24.57
C.D.	1.90	1.81	2.11	2.10	1.51	1.59

TOTAL YIELD (DRY WEIGHT OF GRAINS AND CHAFF PER PLANT)

Yield differed significantly in all the three varieties as a result of defoliation, effected at panicle emergence as well as at anthesis. The interaction between variety and stage and that between minor and major treatments were significant (Appendix II).

Percentage reduction in yield

Table IV A shows per cent reduction in yield in all the varieties, on defoliation. Complete defoliation reduced yield by 39.73 per cent and 22.35 per cent in Jyothi, 39.6 per cent and 26.5 per cent in Ptb.10 and 37.55 per cent and 24.57 per cent in Jaya at panicle emergence and anthesis respectively. Yield reductions were greater when the number of leaves defoliated was more, one leaf $<$ two leaves $<$ three leaves $<$ complete defoliation. Defoliation of flag leaf and penultimate leaf showed minor differences in effect but these were not significant. Flag leaf and penultimate leaf when removed alone resulted in greater and significant yield reductions when compared to the defoliation of the third leaf.

Varietal differences

The mean yield of the two stages of defoliation in the different varieties is given in table IV B. Significant differences in yield were found to exist among the three varieties, Jaya giving the highest yield followed by Jyothi

Table IV B. Yield (in gm) and percentage of reduction (Average of two stages).

Treatment	Jyothi		Ptb.10		Jaya	
	Yield	Percent reduction	Yield	Per cent reduction	Yield	Per cent reduction
F	2.681	10.66	2.206	16.79	3.123	13.32
P	2.653	11.60	2.258	14.82	3.153	12.49
F+P	2.386	20.49	2.073	21.80	2.841	21.15
P'	2.776	7.50	2.528	4.64	3.273	9.16
F+P'	2.491	16.99	2.125	19.84	2.918	19.01
P+P'	2.353	21.59	2.040	23.05	2.806	22.12
F+P+P'	2.180	27.36	1.856	29.99	2.555	29.09
D-	2.083	30.59	1.775	33.04	2.478	31.22

Yield in No defoliation (Control)

Jyothi - 3.001

Ptb.10 - 2.651

Jaya - 3.603

C.D. = 0.064

Table IV C. Yield (in gm) and percentage of reduction (Average of all varieties).

Treatment	Panicle emergence		Anthesis	
	Yield	Per cent reduction	Yield	Per cent reduction
F	2.547	17.60	2.793	9.49
P	2.585	16.37	2.791	9.56
F+P	2.276	26.37	2.591	16.04
P'	2.782	10.00	2.936	4.86
F+P'	2.366	23.46	2.656	13.93
P+P'	2.222	28.11	2.577	16.49
F+P+P'	1.988	35.68	2.405	22.07
D-	1.891	38.82	2.333	24.40

Yield in No defoliation (Control)

Panicle emergence = 3.091

Anthesis = 3.086

C.D. = 0.074

and Ptb.10 respectively. Increasing the number of leaves defoliated was accompanied by a progressive decrease in yield. The difference in yield found on the removal of three leaves when compared with complete defoliation was significant in the short duration varieties, but not in Jaya. Removal of three leaves led to significantly lower yields when compared to the removal of two leaves. Significant differences did not exist between flag leaf removal and penultimate leaf removal. But their effect differed significantly from that of the third leaf.

Stage of defoliation and yield

Average yield of all the three varieties on defoliation at panicle emergence and anthesis is given in table IV C. Enhancing the severity of defoliation resulted in progressive reductions in yield at both stages. Defoliation at panicle emergence had a more pronounced adverse effect on yield than defoliation at anthesis. The yield reduction due to complete defoliation at panicle emergence was one and a half times that recorded on defoliation at anthesis. The adverse effect on yield due to the various defoliation treatments were in the following order viz., complete defoliation > defoliation of two leaves > defoliation of one leaf, the differences between them being significant.

Table IV D. Yield in gm (Average of defoliation treatments including control).

Stage of defoliation	Jyothi	Ptb.10	Jaya
Panicle emergence	2.322	2.045	2.882
Anthesis	2.703	2.291	3.062

C.D. = 0.043

Table IV E. Interaction of defoliation treatments on yield (Percentage).

	Jyothi		Ptb.10		Jaya	
	S_1	S_2	S_1	S_2	S_1	S_2
FXP	+1.40	+1.59	+6.20	+3.01	+1.38	+0.74
FXP'	+1.12	+1.04	+2.27	-1.65	+1.49	+1.08
PXP'	-1.06	-0.29	-2.80	-1.50	-0.65	-0.97
FXPXP'	+0.27	+0.39	+0.03	-0.56	+0.16	+0.54

Mean yield of all treatments

Table IV D provides the average yield of all treatments including control. It was found earlier that differences in yield existed among varieties, and that defoliation effected at panicle emergence and anthesis led to reductions in yield. Data reveals that yield reduction on defoliation at panicle emergence was significantly higher than that at anthesis.

Interaction of defoliation treatments on yield

Interaction effect (Table IV E) on the removal of the upper three leaves was positive at both stages, in all the varieties with one exception in Ptb.10 in which it was negative at anthesis. The interaction effect exhibited by penultimate leaf together with the third leaf was negative in all the varieties. The removal of the flag leaf with the third leaf produced positive interaction in all the varieties at both stages, except in Ptb.10 in which there was negative interaction at anthesis. Interaction effect of flag leaf and penultimate leaf was uniformly positive.

NUMBER OF UNFILLED GRAINS PER PLANT

Analysis of variance of transformed values (Appendix III) reveals that defoliation lead to significant differences in the number of unfilled grains produced, between stages and varieties. Stage x variety, and major x minor treatment interactions were significant.

Table V A. Percentage reduction in number of filled grains

Treatment	V_1		V_2		V_3	
	S_1	S_2	S_1	S_2	S_1	S_2
D+	0	0	0	0	0	0
F	12.28	0.01	22.94	5.26	15.63	3.41
P	15.57	1.17	17.94	3.22	17.87	4.99
F+P	22.46	3.22	27.94	9.36	23.57	10.76
P'	9.88	0.01	6.76	3.51	12.65	1.84
F+P'	18.56	1.17	23.53	12.57	22.33	7.35
P+P'	20.36	2.05	30.00	10.23	26.05	10.76
F+P+P'	31.44	3.80	32.65	15.20	33.01	13.12
D-	32.93	6.44	34.41	15.21	34.24	16.28
C.D.	1.90	1.85	1.90	1.85	1.57	1.66

NUMBER OF FILLED GRAINS PER PLANT

The number of filled grains that developed on defoliation differed significantly between stages and varieties. Stage x variety and major x minor treatment interactions were also significant (Appendix IV).

Percentage reduction in number of filled grains

Table V A provides the per cent reduction in the number of filled grains per plant, on defoliation. Number of filled grains was reduced as a result of defoliation, the reductions being more pronounced when the leaf area removed was greater and were in the following order, one leaf < two leaves < three leaves < complete defoliation. The third leaf showed the least influence on filled grain number. The contribution of the flag leaf and penultimate leaf were similar generally whereas their individual contributions were greater than that of the third leaf.

Varietal differences

The mean number of filled grains at the two stages of defoliation is presented in table XV B. There was no significant difference in the number of filled grains between the two short duration varieties, whereas in Jaya the number of filled grains was significantly higher. The number of filled grains that formed on complete defoliation differed significantly between varieties. All the treatments

Table V B. Number of filled grains and percentage of reduction (Average of two stages).

Treatment	Jyothi		Ptb.10		Jaya	
	Number of filled grains	Per cent reduction	Number of filled grains	Per cent reduction	Number of filled grains	Per cent reduction
F	106	6.19	98	14.04	118	9.92
P	103	8.85	99	13.16	116	11.45
F+P	98	13.27	92	19.30	108	17.55
P'	108	4.42	108	5.26	121	7.63
F+P'	101	10.62	93	18.42	111	15.27
P+P'	100	11.50	90	21.05	106	19.08
F+P+P'	93	17.70	86	24.56	100	23.66
D-	91	20.35	86	24.56	97	25.95

Number of filled grains in No defoliation (Control)

Jyothi - 113

Ptb.10 - 114

Jaya - 131

C.D. = 4.099

Table V C. Number of filled grains and percentage of reduction (Average of all varieties).

Treatment	Panicle emergence		Anthesis	
	Number of filled grains	Per cent reduction	Number of filled grains	Per cent reduction
F	99	17.50	115	2.54
P	98	18.33	116	2.28
F+P	90	25.00	109	7.63
P'	108	10.00	117	0.85
F+P'	94	21.67	110	6.78
P+P'	89	25.83	109	7.63
F+P+P'	81	32.50	106	10.17
D-	79	34.17	103	12.71

Number of filled grains in no defoliation (Control)

Panicle emergence = 120
Anthesis = 118

C.D. = 3.347

were found to reduce grain number significantly in all varieties. Within the variety there was no significant difference between grain number that formed on complete defoliation and that on removal of the upper three leaves. Differences in effect between the treatments in which two leaves were removed in combination were not significant except in Jaya in which significant differences existed between the combinations of penultimate leaf with third leaf and flag leaf with third leaf. Among individual leaves, there was no significant difference between the effects of flag leaf and penultimate leaf in all the varieties. The third leaf when removed resulted in the lowest reduction in grain number.

Stage of defoliation and grain number

Mean filled grain number of all the three varieties on defoliation at panicle emergence and anthesis is given in table XV C.

It was noted that defoliation at panicle emergence caused a marked reduction in number of filled grains, when compared to that at anthesis. The reduction in the number of filled grains resulting from complete defoliation at panicle emergence was nearly three times that observed on defoliation at anthesis. The number of filled grains formed on defoliation showed a tendency to decrease as the number of leaves removed increased. There was no significant difference

Table V D. Number of filled grains (average of defoliation treatments including control).

Stage of defoliation	Jyothi	Ptb.10	Jaya
Panicle emergence	91	89	107
Anthesis	112	105	117

C.D. = 1.932

between the reduction in number of filled grains that resulted by complete defoliation and the defoliation of the upper three leaves, at panicle emergence as well as anthesis. Unlike that at anthesis, the removal of two leaves at panicle emergence resulted in significant differences between the combinations. Among different leaves the flag leaf and penultimate were found to cause greater reductions in filled grain number compared to that of the third leaf on defoliation. The effects resulting from removal of either flag leaf or penultimate leaf were not significantly different.

Mean filled grain number of all treatments

Table XV D provides the mean number of filled grains of all treatments including control. It was found earlier that defoliation at panicle emergence and anthesis led to reductions in grain number. It is seen from this table that defoliation at panicle emergence led to a greater reduction in filled grain number when compared to that at anthesis. This difference was statistically significant in all the varieties.

1000 GRAIN WEIGHT (DRY WEIGHT)

Analysis of variance (Appendix V) shows that 1000 grain weight differed significantly between stages and varieties as a result of defoliation. The interaction between variety

Table VI A. Percentage reduction in 1000 grain weight.

Treatment	V_1		V_2		V_3	
	S_1	S_2	S_1	S_2	S_1	S_2
D+	0	0	0	0	0	0
F	3.21	9.54	1.64	7.21	3.19	7.35
P	1.57	9.27	2.26	8.76	1.52	4.92
F+P	7.58	13.45	2.26	10.30	6.34	10.86
P'	1.11	7.40	0.40	0.62	0.99	4.23
F+P'	5.84	12.70	2.72	6.71	5.80	10.02
P+P'	9.86	16.04	5.17	8.99	5.49	9.76
F+P+P'	12.65	18.67	10.26	14.63	10.10	15.05
D-	15.20	20.09	10.57	18.09	11.08	15.21
C.D.	3.41	3.32	3.85	3.86	3.28	3.28

and stage was significant. Major x minor treatment interaction was also significant.

Percentage reduction in 1000 grain weight

The table VIA reveals that defoliation tends to decrease 1000 grain weight. Comparison of the influence of different treatments on 1000 grain weight showed that complete defoliation was the most effective in reducing 1000 grain weight followed by removal of three leaves, two leaves and single leaf respectively. The differences between them were not significant. However, significant differences were observed when leaf lamina removed were markedly different from each other in area.

Varietal differences

The mean 1000 grain weight of the two stages of defoliation in the three varieties is presented in table VIB. The reduction in 1000 grain weight due to defoliation differed significantly between varieties. Jaya recorded the highest 1000 grain weight followed by Jyothi and Ptb.10 respectively. In all varieties, the highest reduction in 1000 grain weight was caused by complete defoliation which was followed by the defoliation of three leaves, two leaves and one leaf respectively. Flag leaf removal caused significant differences in 1000 grain weight when compared with penultimate leaf,

Table VI B. 1000 grain weight (in gm) and percentage of reduction (Average of two stages).

Treatment	Jyothi		Ptb.10		Jaya	
	1000 grain weight	Per cent reduction	1000 grain weight	Per cent reduction	1000 grain	Per cent reduction
F	24.768	6.42	22.112	4.42	25.818	5.27
P	25.020	5.47	21.998	4.82	26.228	3.77
F+P	23.675	10.55	21.683	6.28	24.910	8.60
P'	25.330	4.30	23.017	0.51	26.542	2.62
F+P'	24.002	9.31	22.045	4.71	25.098	7.92
P+P'	23.028	12.99	21.498	7.08	25.175	7.63
F+P+P'	22.312	15.70	20.212	12.64	23.827	12.58
D-	21.788	17.68	19.821	14.32	23.670	13.15

1000 grain weight in No defoliation (Control)

Jyothi - 26.467

Ptb.10 - 23.135

Jaya - 27.255

C.D. = 0.243

Table VI C. 1000 grain weight (in gm) and percentage of reduction (Average of all varieties).

Treatment	Panicle emergence		Anthesis	
	1000 grain weight	Per cent reduction	1000 grain weight	Per cent reduction
F	24.800	2.73	23.666	8.04
P	25.138	1.40	23.690	7.97
F + P	24.087	5.53	22.759	11.59
P'	25.278	0.86	24.648	4.25
F + P'	24.251	4.88	23.179	9.96
P + P'	23.740	6.89	22.728	11.71
F + P + P'	22.686	11.02	21.548	16.29
D-	22.351	12.34	21.169	17.77

1000 grain weight in no defoliation (Control)

Panical emergence = 25.496

Anthesis = 25.742

C.D. = 0.198

in the improved varieties. But in the local variety the difference due to flag leaf or penultimate leaf removal was not significant. The effect of the removal of the third leaf was significantly less than that of any of the top two leaves in all varieties.

Stage of defoliation and 1000 grain weight

Mean 1000 grain weight of all the three varieties in minor treatments at panicle emergence and anthesis is given in table VIC. Increasing the number of leaves defoliated led to a progressive decrease in 1000 grain weight. Defoliation at anthesis caused greater reduction in 1000 grain weight as compared to that at panicle emergence. The reduction in 1000 grain weight due to complete defoliation at anthesis is one and a half times that recorded on such defoliation at panicle emergence. The difference in 1000 grain weight between leaf lamina removal at panicle emergence and that at anthesis was always significant in all defoliation treatments. The effect of removal of the upper three leaves was significantly lower than that due to complete defoliation and it was followed by defoliation of two leaves and one leaf respectively. In general significant differences in effect were not observed among the top three leaves except that between flag leaf and penultimate leaf at panicle emergence.

Table VI D. 1000 grain weight in gm (Average of defoliation treatments including control).

Stage of defoliation	Jyothi	Ptb.10	Jaya
Panicle emergence	24.477	22.282	25.848
Anthesis	23.609	21.166	24.934

C.D. = 0.114

Mean 1000 grain weight of all treatments

Table VII shows the average 1000 grain weight of all treatments including control. Defoliation at anthesis led to a greater reduction in 1000 grain weight when compared to that at panicle emergence. This difference was statistically significant in all the varieties.

DISCUSSION

DISCUSSION

The results of the present investigation showed that the three varieties differed among themselves in yield and yield components. Jaya, the medium duration improved variety performed better than the short duration varieties, with higher yield, higher number of filled grains and 1000 grain weight. Yoshida (1972) has reported a positive correlation between growth duration and length of period from panicle initiation to heading. Possibly the number of spikelets per ear in cereal crop can be increased by increasing the length of growth period for the panicle. Cock and Yoshida (1972) pointed out that the major factor responsible for yield differences in rice is grain number. Venkateswarlu et al. (1977) worked out the relationship between growth duration and parameters governing productivity with 21 rice varieties from early, medium, and late duration groups. The study revealed that for realising higher yields, the optimum duration was around 130 to 135 days. It may be noted that Jaya is a medium duration variety of 125 days.

The short duration varieties, Ptb.10 and Jyothi showed differences in yield. Though the grain numbers were similar, Jyothi recorded a better yield as a result of higher grain weight. Yoshida (1972) pointed out that grain weight is quite a stable varietal character.

Comparison of the leaf characters of these varieties brought out important differences. Jaya had higher leaf number than the other two varieties. The number of functional leaves in short duration varieties was only four whereas in Jaya it was five. Consequently Jaya had more leaf area. A close correlation was found between grain yield and LAI in corn at silking (Eik and Hanway, 1966; Okubo and Iwata, 1968 and Tanaka et al. 1969 a). Grain yield of rice is closely correlated with LAI at flowering (Yoshida et al. 1972 a). One of the reasons for the better performance of Jaya was its larger leaf area.

Variation in total chlorophyll per leaf and chlorophyll content per gram of leaf tissue also existed among varieties. The highest chlorophyll content per leaf and chlorophyll content per gram of leaf was met with in Jaya. Brougham (1960) stated that the production of dry matter by pasture and crop species is ultimately limited by the amount of chlorophyll. Reddy and Pyare lal (1976) found poor correlation between chlorophyll content at different stages and grain yield in both triticale and wheat varieties. Palit et al. (1976) reported that irrespective of stages the dwarf varieties showed higher chlorophyll content in both leaf and shoot, which was correlated with their higher grain yield in rice. The higher chlorophyll content in Jaya was another factor which contributed to higher yield.

The study of the leaf angles in the different varieties showed that the leaf angles in Jaya ranged from 8^{0} for the flag leaf and 18^{0} for the fifth leaf. Direct evidence of effect of erect leaves in increasing photosynthesis and hence yields have been reported for rice (Matsushima et al., 1964 and Tanaka et al., 1969b). Tanner et al. (1966) have shown the extreme usefulness of leaf angle and leaf width for selection of high yielding varieties. Duncan (1967) predicted from mathematical models that leaf angles less than 19^{0} might increase the efficiency of Co_2 fixation, even more particularly when a high LAI is present. Tanaka et al. (1969 b) demonstrated by mechanical manipulation that a horizontally leaved canopy showed a low photosynthetic rate while an erect leaved canopy showed a high photosynthetic rate and increased its photosynthesis with increasing LAI. The higher photosynthetic activity of an erect leaved canopy produced higher grain yield. Pendleton et al. (1968) also showed that the corn canopies with leaves positioned upright by mechanical manipulation gave higher yields than the untreated canopy. As pointed out by Yoshida (1972) the beneficial effect of upright leaves result from greater illumination of the leaves. Among several leaf characters associated with high yielding ability erect leaf habit seems the most important (Yoshida, 1972). Leaf angle has been used successfully as a selection criterion for breeding high yielding rice varieties at IRRI (Yoshida et al., 1972 a).

Differences existed in the performance of the short duration varieties, Jyothi the dwarf variety and Ptb.10 the tall variety. Jyothi gave higher yields than Ptb.10 though Ptb.10 had 40 per cent more leaf area. The total chlorophyll content per plant was also higher in Ptb.10. However the chlorophyll content per gram of leaf tissue was more in Jyothi. It appears that the photosynthetic efficiency of Jyothi was better as the higher yields in Jyothi indicate. Comparison of the culms of Jyothi and Jaya showed that Jyothi had short, stiff and upright culm whereas Ptb.10 was tall and lodging. An upright culm permits greater penetration of incident light into canopy (Tsunoda, 1964) and Tanaka et al. 1966). The leaf angles in Jyothi ranged from 10° to 32° whereas the leaf angles in Ptb.10 ranged from 55° to 84°. Jyothi had erect leaves permitting better illumination. The much wider leaf angles and the drooping nature of the leaves in Ptb.10 resulted in mutual shading.

In rice and corn compared with the leaf blades net photosynthesis of ear and sheath is very low and sometimes it is negative (Takeda and Maruta, 1956; Matsushima, 1957; Tanaka, 1958 a; Tanaka et al. 1971 and Yoshida and Cock, 1971). The ears of improved rice varieties tend to bend and are positioned below the flag-leaf and hence do not shade the leaf canopy (Yoshida, 1972), but not so in Ptb.10. The higher yields obtained in Jyothi were due to better illumination of its leaves when compared with Ptb.10, whose leaves received less light due to shading by other leaves and the panicle.

DEFOLIATION STUDIES

Reductions in yield and yield components following defoliation at panicle emergence and anthesis gave a general picture of the relative contribution of the different leaves to grain filling at these stages. The effect of defoliation followed similar trends in all the varieties and the reductions in yield were in the order, defoliation of all leaves > defoliation of three leaves > defoliation of two leaves > defoliation of one leaf.

Complete defoliation

Though leaf area lost on complete defoliation differed in the three varieties the reduction in yield was more or less similar ranging from 30.59 to 33.04 per cent.

The per cent reduction in filled grain number and 1000 grain weight also were not markedly different. Such reductions in yield on complete defoliation have been observed in other crops as well as in rice. In rice complete defoliation at flowering decreased the ripening percentage to 36 per cent of the control (Matsushima, 1957), and the grain weight to 55 per cent in one example (Takeda and Maruta, 1956), and 81 per cent to 88 per cent in another (Owen, 1968). Venkateswarlu (1976) found that removal of all leaves at flowering resulted in only 30 per cent of grains maturing compared with 55 per cent in control and a reduction in grain yield of 50 per cent. These estimations, however, are subject to large variation due to such sources as the amount of stored carbohydrate, timing of defoliation treatment and panicle size.

The results indicated that sources other than leaves, also contributed to grain filling in rice. Apart from the leaves, the sources that contribute to grain filling are stored carbohydrate, and photosynthesis by plant parts other than leaf lamina. The reported estimates of the loss of carbohydrate from the vegetative parts are 0 to 40 per cent for rice depending upon the rate of nitrogen application and growth duration (Togari et al. 1954; Murayama et al. 1955; Takeda and Murata, 1956; Soga and

Nozaki, 1957; Wada, 1969 and Yoshida and Ahn, 1968), 20 per cent for barley (Archbold and Mukerjee, 1942), 5 to 10 per cent to less than 50 per cent for wheat (Asana and Joseph, 1964; Barnell, 1936 and Wardlaw and Porter, 1967) and 12 to 14 per cent for corn (Duncan and Hatfield, 1965; and Tanaka and Ishizuka, 1969). It is to be noted that part of the carbohydrates thus lost from vegetative parts might have been consumed in respiration. Cook and Yoshida (1972) showed that under normal field conditions the amount of the carbohydrate translocated from the vegetative parts was equal to about 21 per cent of grain carbohydrate.

The estimated contribution of ear photosynthesis to the grain ranges from 8 to 23 per cent for rice (Enyi, 1962 and Takeda and Murata, 1956), 10 to 49 per cent for wheat (Boonstra, 1929 and Kriedemann, 1966) and 26 to 76 per cent for barley (Watson et al. 1958 and Frey-Wyssling and Buttrose, 1959). In rice and corn compared with the leaf blades net photosynthesis of ear and leaf sheath is very low; some times it is negative (Yoshida, 1972). The contributions of reserve food, stem, panicle and leaf to yield was 14.7, 18.1, 19.7 and 47.5 per cent respectively in Jaya; and 12.7, 19.7, 13.1 and 54.5 per cent respectively in Sona (Venkateswarlu, 1976). Such great variations in contributions to grain filling could be attributed to differences in techniques employed, varietal differences and differences in growing conditions (Yoshida, 1972).

Defoliation of the top three leaves

Removal of the top three leaves resulted in drastic reduction in leaf area, the reductions in leaf area in short duration varieties viz., Ptb.10 and Jyothi were 114.02 sq.cm and 80.29 sq.cm respectively, whereas in Jaya it was 99.42 sq.cm. The per cent reduction in leaf area in Ptb.10 and Jyothi was 73.18 and 72.89 respectively whereas it was only 55.4 in case of Jaya. The difference in leaf area reduction was due to the fact that Jaya had two leaves left intact when compared with Jyothi and Ptb.10 which had only one leaf each. The contribution of the leaves (fourth leaf in short duration varieties and the fourth and fifth leaf in Jaya) thus retained in the plants, was not substantial in grain filling. This was evidenced from the fact that their presence did not improve the total yield, grain number, and 1000 grain weight by not more than a few per cent. Tanaka (1958 b) pointed out that the top three leaves are important for grain filling in rice. The relatively small contribution of the fourth and fifth leaves was due to various reasons. Bonnemain (1965) pointed out that in tomato the lower leaves act as the main source of assimilates for roots. Tanaka (1958 a) found that the lower leaves in rice sent their assimilates to the roots. The progressive decline in apparent photosynthesis with increasing age of leaf may also be an important factor as was found in tall fescue by Jewiss and Woledge (1967). The leaf angles of the lower leaves were relatively large. They were drooping and shaded and received less illumination. The chlorophyll content of these leaves also were low. Another factor for low contribution may be the distance from the panicle. Eastin (1969) and Palmer (1969) working with corn found that the translocation of the assimilates by the leaves below the ear sharply decreases, the lower the leaf positions.

Defoliation of two leaves in combinations

The top three leaves were defoliated two at a time in three combinations, viz., penultimate leaf and flag leaf, penultimate leaf and the third leaf and flag leaf and the third leaf and the relative effects studied.

The removal of penultimate leaf and the third leaf together decreased leaf area by 51.06 per cent in Jyothi, and 50.61 per cent in Ptb.10 and 39.91 per cent in Jaya. This was followed by the combination of flag leaf with third leaf and flag leaf with penultimate leaf respectively.

The highest reductions in yield, filled grain number and 1000 grain weight were caused by the removal of penultimate leaf and the third leaf together in all the varieties and this reduction was related to leaf area lost. The relative importance of the second and third leaves to grain filling was pointed out by Tanaka (1958 b). Yoshida (1972) found that the photosynthetic activity of the second and third leaves in rice was higher than that of the flag leaf at early stages of ripening.

The adverse effect on yield and yield components on the defoliation of flag leaf and penultimate leaf was slightly less though there were significant differences in leaf area. The smaller area of the flag leaf was to a large extent compensated by its higher photosynthetic efficiency and nearness to panicle when compared with the third leaf. Results obtained in the present study showed that the contribution of the top two leaves in the three varieties ranged from 20.49 to 21.15 per cent. Similar results were obtained by Sikder and Das Gupta (1976). They found by defoliation of the top two leaves in rice, that their contribution was 20.9 per cent as an average of two varieties.

Removal of the flag leaf with the third leaf resulted in the least reductions in yield when compared with the other two combinations. This indicates that the third leaf was comparatively less important than the other two leaves in grain filling. The low contribution of the third leaf is the result of its age, relative position, lower chlorophyll content, higher leaf angle and shading.

Defoliation of single leaves

Defoliation of the third leaf

The third leaf had completed its growth at or before panicle emergence and hence its area did not record any change after panicle emergence. The top three leaves are important for grain filling in rice (Tanaka, 1958). Yoshida (1972) observed that the photosynthetic activity of the second and third leaves in rice was higher than that of the flag leaf at early stages of ripening. The present studies indicated that the contribution of the third leaf in yield and yield components was less than that of either flag leaf or penultimate leaf though its area was larger than that of flag leaf or penultimate leaf. This comparatively low contribution might be due to low chlorophyll content, decrease in photosynthetic efficiency due to ageing, a wider leaf angle and shading, and greater distance from the panicle when compared with the other two leaves.

Defoliation of penultimate leaf

The area of the penultimate leaf was less than that of the third leaf but more than that of the flag leaf. The reductions in yield and filled grain number resulting from penultimate leaf removal were found to be higher than those caused by the defoliation of the third leaf in all the varieties. The influence of clipping the penultimate leaf was also reflected in minor differences in 1000 grain weight.

The penultimate leaf continued to grow even after panicle emergence as shown by the higher leaf area at anthesis. This implied that its photosynthetic efficiency was high. Saeki (1959) observed that each leaf showed a maximum rate of photosynthesis before it was fully expanded followed by a progressive decline in Phaseolus viridissimus and Fagophyrum esculentum. The factors which contributed to the photosynthetic efficiency of the penultimate leaf were, higher leaf area, high chlorophyll content, smaller leaf angle and less shading, its nearness to the panicle and its age in relation to the third leaf.

Flag leaf defoliation

The flag leaf area of dwarf varieties at anthesis was less than that of the penultimate leaf, Jaya having 30.13 sq.cm and Jyothi 25.9 sq.cm. The flag leaf size of most improved rice varieties is relatively small compared with the second or third leaves. Possibly this results from competition between developing flag leaf and panicle for assimilates. The mechanism involved in the partitioning of assimilation products between the flag leaf and panicle was not understood (Yoshida _et al_. 1972 b). Similarly, in wheat the ear size may be negatively correlated with flag leaf area (Rawson, 1970).

The flag leaf area and penultimate leaf area was similar at anthesis in the tall variety. Though differences existed in the area of the flag leaf and penultimate leaf in the dwarf varieties, the contribution of these leaves to grain filling appeared to be of the same magnitude. The flag leaf contribution to grain yield ranged from 10.66 per cent to 16.79 per cent. Reports of a similar nature have been recorded by others also. Boonstra (1937) reported that in wheat 60 per cent of the dry matter in the grain was derived from the flag leaf lamina, sheath and peduncle, 17 per cent from the parts of shoot below the base of the flag leaf. Rawson and Hofstra (1969) found that in wheat the rates of Co_2 fixation by the whole flag leaf were higher than the basal leaves. The removal of half the flag leaf at panicle emergence reduced the grain yield in rice by 14 per cent and grain number by 15 per cent whereas complete removal of flag leaf reduced grain yield by 19 per cent (Tripathi and Purohit, 1971). Rama Das and Raghavendra (1974) observed that in millets the photochemical activities of flag leaf were consistent with the high photosynthate contribution to the grain filling process. In four crop plants (*Oryza*, *Pennisetum*, *Sorghum*, *Zea*) the rate of carbon fixation was higher for the flag leaf, decreasing gradually in the lower leaves (Rama Das and Rajenderudu, 1977).

It is seen from the table V C that the reduction in grain number caused by the excision of the flag leaf and penultimate leaf are not different. However varieties differed with respect to the extent of reduction in grain number. The highest reduction of 14.04 per cent was met with in Ptb.10. Tripathi and Purohit (1971) reported similar results. They obtained a 13 per cent reduction in filled grain number in paddy by defoliation of flag leaf.

Significant reductions in 1000 grain weight followed defoliation of the flag leaf in all the varieties. Differences were also noted between varieties. In the improved varieties, the contribution of the flag leaf to 1000 grain weight was more than that of the penultimate leaf whereas in the local variety, the penultimate leaf appeared to contribute more than the flag leaf. In defoliation experiments with oats, the presence of flag leaf and penultimate leaf increased individual grain weight (Frey, 1962). Lucas and Asana (1968) reported that the removal of the flag leaf and penultimate leaf reduced both grain number and grain weight in wheat. The leaf area of the flag leaf was found to be less than that of the penultimate leaf. But the contribution of both these leaves to yield and yield components appeared to be similar. The small size of the flag leaf was compensated by better photosynthetic efficiency due to its erect nature, absence of shade from other leaves, higher chlorophyll content, closeness to the panicle and young age when compared with the penultimate leaf.

COMPENSATION MECHANISM

If a part of green tissue is removed or shaded the photosynthetic rate of the remaining green tissue increases Yoshida (1972). Austin and Jones (1974) reported that compensation mechanisms exist in cereals. Table IV E summarises the interaction of defoliation of leaves on yield.

<u>Interaction of flag leaf, penultimate leaf and the third leaf on yield</u>

It was found that the defoliation of flag leaf, penultimate leaf and the third leaf together resulted in positive interactions in all varieties and stages except in Ptb.10 at anthesis. The removal of these three leaves affected the light environment of the remaining plant parts viz., leaf sheath, stem and the panicle. The photosynthesis by these structures partially compensated for the loss of leaf area. Lucas and Asana (1968) in wheat and Rangasayi and Venkateswarlu (1972) in finger millet had reported that the yield decrease due to leaf clipping was little as the mobilization of stem sugars and flag leaf photosynthesis compensated for the yield losses. Venkateswarlu (1976) observed that the yield loss depends not only on the type of crop but on the degree of leaf clipping effected. The estimated contribution of ear photosynthesis to the grain ranges from 8 to 23 per cent for rice Enyi (1962), and 10 to 49 per cent for wheat Boonstra (1929) and Kriedemann (1966), indicating that panicle contribution to yield is greater in wheat than in rice.

The greatest efficiency of leaf in maize was attained at ear formation where there was a rapid movement of assimilates from the leaves (Yermilov, 1962). Demand for assimilates can also influence the rate, velocity, and pattern of translocation in wheat, Wardlaw (1965) and Rawson and Evans (1970) and presumbaly in other plants. Evans (1972) pointed out that demand for assimilates influence photosynthetic rate and such feedback effects on photosynthesis may occur in rice as they do in wheat at about anthesis. The defoliation of the top three leaves led to a greater demand for assimilates which stimulated the photosynthetic rate in the remaining green parts.

Interaction of penultimate leaf and the third leaf

The removal of penultimate leaf and the third leaf together resulted in negative interaction. Bonnemain (1965) pointed out that in tomato the lower leaves act as the main source of assimilates for roots, whereas the upper leaves perform this function for the shoot apex, and leaves in an intermediate position may supply assimilates in either or both directions. Lupton (1966) found that the translocation of assimilates from the flag leaf in wheat was entirely towards the grain whereas the translocation from the second or the third leaves was partly towards the grain and partly downwards. Evans (1972) observed that when the lower leaves in wheat are shaded the flag leaf has to support the rest of the plant. Such partitioning of assimilates between grains and the lower portions of the plant appeared to be an important reason for negative interaction. The defoliation of the second and third leaves led to the partitioning of assimilates of the flag leaf between the grains and the lower portions of the plant in response to their demand for assimilates.

Interaction of flag leaf and the third leaf

Here also positive interaction was observed, except in the case of Ptb.10 at anthesis. Positive interaction might be due to the improvement in the light environment of the remaining plant parts, the mobilization of storage sugars and the enhanced photosynthesis caused by the higher demand for assimilates.

Interaction of flag leaf and penultimate leaf

Positive interaction was evident on the removal of flag leaf and penultimate leaf together. The basis of such compensation may be found in the explanations already given, viz., better illumination of the remaining plant parts, mobilization of storage sugars and higher photosynthetic rates in response to the demand for assimilates.

Klinck and Sim (1976) working with spring oat cultivars Clintland 60, and Garry found that the compensation mechanism was insufficient to meet grain fillingrequirements. Neverthless, they found some evidence of compensation effects particularly in the cultivar Clintland 60. They indicated that differences may exist among varieties in their ability to compensate for lost parts. The lack of compensation effects shown by Ptb.10 could be a varietal character.

IMPORTANCE OF THE PERIOD BETWEEN PANICLE EMERGENCE AND ANTHESIS IN GRAIN FILLING

The flag leaf and the penultimate leaf continued to grow even after panicle emergence. As a result the leaf area lost on defoliation at anthesis was more than that at panicle emergence. Leaf removal at panicle emergence, however, resulted in greater reduction, in yield and filled grain number when compared with that at anthesis. Reduction on yield on defoliation at panicle emergence was one and a half times that at anthesis, whereas reduction in filled grain number was nearly 3 times.

Comparable results have been reported by Klinck and Sim (1976). They found that the yield reduction in oats resulting from defoliation at panicle emergence was twice that at anthesis.

1000 grain weight was also reduced by defoliation. The reduction in 1000 grain weight due to defoliation at anthesis was nearly one and a half times that resulting from defoliation at panicle emergence.

The results of the present investigation revealed that the period between panicle emergence and anthesis is important in grain filling in rice. Damage to the leaves by insects or other agents or severe leaf disease infection at the early heading stage could have drastic effects on grain yield in rice.

SUMMARY

SUMMARY

Defoliation was effected at panicle emergence and anthesis for assessing the contribution of leaves and the importance of the period between panicle emergence and anthesis to grain filling. A split plot experiment was laid out in Randomised Block Design with three replications.

Jaya, the medium duration dwarf variety was superior to the short duration varieties in yield, grain number and 1000 grain weight. The plant characters which contributed to higher yield in Jaya were, erect culm, and erect leaves permitting better illumination of the leaves, larger leaf area due to a greater number of functional leaves, absence of shading by higher chlorophyll content and the positioning of the panicle below the flag leaf. The short duration varieties, Jyothi, a dwarf variety and Ptb.10 a tall variety differed in yield. The superior yield of Jyothi was due to higher 1000 grain weight as the grain number in these varieties were found to be similar. Ptb.10 had decided by more leaf area than Jyothi. The higher yield recorded by Jyothi inspite of its smaller leaf area might be due to its erect culm and leaves allowing better light environment, and the bending of the ears well below the flag leaf. The low

yield in Ptb.10 was the result of plant characters like lodging culm, drooping and mutually shading leaves, and the erect panicle which shaded the leaves.

Reductions in yield and yield components following defoliation at panicle emergence and anthesis gave a general picture of the relative contribution of different leaves to grain filling at these stages. The reductions in yield and yield components generally followed similar patterns in all varieties, defoliation of all leaves > defoliation of three leaves > defoliation of two leaves > defoliation of one leaf.

The results of complete defoliation indicated that apart from the leaves other sources also contributed to grain filling. These could be stored carbohydrate and photosynthesis by plant parts other than leaf lamina.

It was found that only the top three leaves are important in grain filling in rice. The contribution of the third leaf is smaller than any of the other two leaves. The flag leaf and penultimate leaf contributed almost equally to grain filling.

Defoliation stimulated the photosynthetic activity of the remaining green parts. Positive interaction resulted on the defoliation of the top three leaves, flag leaf and penultimate leaf, flag leaf and third leaf. Positive interactions are the result of improvement in light environment of remaining plant parts, enhanced photosynthetic rates in response to demand for assimilates and the mobilization of stem sugars. Negative interaction observed on the defoliation of penultimate leaf and third leaf appeared to be caused by the partitioning of carbohydrates between grains and the rest of the plant and loss of carbohydrates on maintenance respiration.

Defoliation at panicle emergence and anthesis depressed yield and yield components. Reduction in yield on defoliation at panicle emergence was one and a half times that at anthesis, whereas reduction in filled grain number was nearly three times that at anthesis. 1000 grain weight reduction on defoliation at anthesis was one and a half times that at panicle emergence. These results indicated that damage to the leaves by insects, diseases or other agents at the early heading stage could have drastic effects on grain yield in rice.

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*Original not seen

APPENDICES

APPENDIX I

Analysis of variance
Leaf area removed

Source	S.S.	df	M.S.	F
Total	303806.4960	161		
Block	0.0682	2	0.0340	Less than one
Major treatment	13250.7490	5	2650.1490	37326.042**
Stage (S)	761.6270	1	761.6270	10727.14**
Variety (V)	12461.3385	2	6230.6690	87755.901**
V x S	27.7836	2	13.8910	195.647**
E (1)	0.7110	10	0.0710	
Minor treatment	277092.9750	8	34636.6210	407489.658**
F	32107.8610	1	32107.8610	377739.541**
P	38634.5230	1	38634.5230	454523.800**
F x P	32.6420	1	32.6420	384.023**
P'	45372.5500	1	45372.5500	533794.705**
F x P'	12.7090	1	12.7090	149.517**
P x P'	18.0760	1	18.0760	212.658**
F x P x P'	19.1400	1	19.1400	225.176**
D (-)	160895.4740	1	160895.4740	1892887.929**
Major x Minor	13453.7790	40	336.344	3956.988**
E (2)	8.24	96	0.085	

**Significant at 0.01 level probability

APPENDIX V

Analysis of variance
1000 grain weight

Source	S.S.	df	M.S.	F
Total	689.2124	161		
Block	0.0564	2	0.0282	Less than one
Major treatment	409.7773	5	81.9554	2295.6694**
Stage (S)	25.4510	1	25.4510	712.9131**
Variety (V)	371.5150	2	185.7575	5203.2913**
V x S	12.8142	2	6.4071	179.4705**
E (1)	0.3574	10	0.0357	Less than one
Minor treatment	227.4113	8	28.4267	94.5094**
F	50.6351	1	50.6351	168.1671**
P	64.1735	1	64.1735	213.1302**
F x P	0.6175	1	0.6175	2.0508**
P'	30.1676	1	30.1676	100.1913**
F x P'	0.0004	1	0.0004	Less than one
P x P'	3.6259	1	3.6259	12.0400**
F x P x P'	0.1554	1	0.1554	Less than one
D (-)	77.7777	1	77.7777	258.3700**
Major x Minor	22.7000	40	0.5675	1.8800**
E (2)	28.9100	96	0.3011	

**Significant at 0.01 level probability

APPENDIX III

Analysis of variance (after angular transformation)
Number of unfilled grain

Source	S.S.	df	M.S.	F
Total	6136.2400	161		
Block	9.8700	2	4.9350	1.4850
Major treatment	1659.5809	5	331.9160	99.911**
Stage (S)	1218.3693	1	1218.3693	366.7467**
Variety (V)	369.2118	2	184.6059	61.5350**
V x S	71.9990	2	35.9995	10.8362**
E (1)	33.2210	10	3.3221	
Minor treatment	3634.3287	8	454.2910	470.4753**
F	766.3500	1	766.3500	793.6516**
P	1043.8200	1	1043.8200	1081.0066**
F x P	85.1600	1	85.1600	88.1938**
P'	488.6300	1	488.6300	506.0376**
F x P'	0.0700	1	0.0700	Less than one
P x P'	19.0500	1	19.0500	19.7286**
F x P x P'	85.1600	1	85.1600	88.1938**
D (-)	1146.0800	1	1146.0800	1186.9096**
Major x Minor	706.5390	40	17.6634	18.2823**
E (2)	92.7004	96	0.9656	

**Significant at 0.01 level probability

APPENDIX IV

Analysis of variance
Number of filled grain

Source	S.S.	df	M.S.	F
Total	32586.031	161		
Block	223.031	2	111.515	10.98**
Major treatment	17513.438	5	3502.687	344.888
Stage (S)	10129.389	1	10129.389	997.379**
Variety (V)	6683.568	2	3341.784	329.045**
V x S	700.481	2	350.240	34.486**
E (1)	101.562	10	10.156	
Minor treatment	11450.197	8	1431.375	1057.145**
F	2773.770	1	2773.770	2048.579**
P	3906.250	1	3906.250	2884.970**
F x P	177.777	1	177.777	131.297**
P'	1547.111	1	1547.111	1162.562**
F x P'	17.361	1	17.361	12.822**
P x P'	9.000	1	9.000	6.646**
F x P x P'	0.027	1	0.027	Less than one
D (-)	3018.892	1	3018.892	2229.610**
Major x Minor	3167.729	40	79.193	58.488**
E (2)	130.074	96	1.354	

**Significant at 0.01 level probability

APPENDIX II

Analysis of variance

Total yield

Source	S.S.	df	M.S.	F
Total	36.1332	161		
Block	0.1661	2	0.0830	16.60
Major treatment	20.7964	5	4.1592	831.84**
Stage (S)	2.9282	1	2.9282	585.64**
Variety (V)	17.5828	2	8.7914	1758.28**
V x S	0.2854	2	0.1427	28.54**
E (1)	0.0503	10	0.0050	
Minor treatment	13.9206	8	1.7400	1450.00**
F	3.3672	1	3.3672	2806.00**
P	4.4802	1	4.4802	3733.50**
F x P	0.2146	1	0.2146	178.33**
P'	1.8769	1	1.8769	1564.08**
F x P'	0.0336	1	0.0336	28.00**
P x P'	0.0420	1	0.0420	35.00
F x P x P'	0.0008	1	0.0008	Less than one
D (-)	3.9053	1	3.9053	3254.41**
Major x Minor	1.0792	40	0.0269	22.41**
E (2)	0.1206	96	0.0012	

**Significant at 0.01 level probability

PLATES

Plate I. Leaf area growth after panicle emergence

A. Flag leaf continued to grow after panicle emergence and the growth was more sricking than that of penultimate leaf (in all the three varieties).

B. Penultimate leaf also continued to grow after panicle emergence (in all the three varieties)

PLATE I A

PLATE I B

Plate I. C. The leaf lower to the penultimate leaf attained maximum growth at panicle emergence and there was no further growth after panicle emergence (in all the three varieties).

Plate II. Plant characters (Ten days after anthesis)

A. Jyothi dwarf plant (with erect small leaves, non-lodging habit and panicle positioned below the flag leaf)

PLATE I c

PLATE II A

Plato II. B. Ptb.10 tall plant (with drooping lower leaves, lodging habit and flag leaf positioned below the paniole)

C. Dwarf plant, with more erect leaves, non-lodging habit, and panicle positioned below the flaf leaf.

PLATE II B

PLATE II C

V3

Plate III. <u>Yield and yield components</u> (Representative sample of a control plant)

A. Panicle length (Length of the panicle was more in Ptb.10 followed by Jaya and Jyothi whereas the grains were scattered in Ptb.10, densly packed in Jyothi and most densly packed in Jaya).

B. Size and number of filled grains (Representative sample of a control plant).
In both Ptb.10 and Jyothi, number of filled grains were almost similar whereas the size of latter was bigger than the former, Jaya was having no grains with the largest size).

PLATE III.B

PLATE III. A

EFFECT OF DEFOLIATION AT PANICLE EMERGENCE AND ANTHESIS ON GRAIN YIELD IN RICE

(Oryza sativa L.)

By

SYED MOSHIN IBRAHIM

ABSTRACT OF THE THESIS

SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENT FOR THE DEGREE

MASTER OF SCIENCE IN AGRICULTURE

(AGRICULTURAL BOTANY)

FACULTY OF AGRICULTURE

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF AGRICULTURAL BOTANY

COLLEGE OF AGRICULTURE, VELLAYANI

TRIVANDRUM

1978

ABSTRACT

The contributions of the different leaves and the importance of the period between panicle emergence and anthesis to grain filling in three varieties of rice were studied by employing the defoliation technique. Jaya, a medium duration dwarf variety recorded the highest yield and yield components. Of the two short duration varieties the dwarf variety Jyothi performed better than the tall variety Ptb.10. Increasing the severity of defoliation resulted in further reductions in yield. It was found that only the top three leaves are important in grain filling in rice. The contribution of the third leaf is lower than any of the other two leaves. Flag leaf and penultimate leaf are of equal importance in grain filling in rice. Defoliation stimulated the photosynthetic activity of the remaining green parts which compensated partially for loss of leaves. A short period of eight days between panicle emergence and anthesis was found to be important in grain filling in rice. Damage to the leaves by insects, diseases or other agents at the early heading stage could have drastic effects on grain yield in rice.