Mechanism Of Nitrogen Response In The High Yielding Varieties Of Rice

II. Effect of Nitrogen Manuring on Carbohydrate Content of Various Plant Parts

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This is to certify that the thesis entitled " Mechanism of nitrogen response in the high yielding varieties of rice. II. Effect of nitrogen manuring on carbohydrate content of various plant parts " submitted in partial fulfilment of the requirements for the degree of Master of Science in Agriculture(Chemistry) is a record of bonafide research work carried out by Sri Bijayananda Mishra in the chemical laboratory of the College of Agriculture, Bhubaneswar under my guidance and supervision during the session 1970-71.

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CHAPTER-I

INTRODUCTION

I N T R O D U C T I O N

A number of high yielding varieties are now under cultivation in different parts of India. All these varieties have many desirable morphological characters such as: narrow, erect and thick green leaves, short, sturdy culm and moderately large number of tillers so as to give them an ideal plant type. These varieties also are highly nitrogen responsive and are intensitive to photoperiod.

The old varieties which were grown in India so far, were tall, leafy and heavy tillering. They were also low nitrogen responsive and majority of them were season bound. Under high fertility conditions they grew excessively tall and leafy and lodged before harvest resulting in very low yield.

In the breeding programme for high yielding varieties the above differences in plant type and nitrogen responsiveness between high yielding and tall varieties are now taken into consideration. The difference between the high yielding and tall varieties at physiological or biochemical level however are not known. Most of the early work by Japanese worker in this area were confined to comparisions between high yielding Japonica varieties and low yielding tall indica varieties. These results are found not to hold good for most of the recently developed high yielding varieties as almost all these varieties are pure indicas.

Important differences between high yielding japonica varieties and tall indica varieties with respect to their carbohydrate metabolism have been reported by Japanese workers (Baba, 1961, Tanaka, 1966). A study was undertaken to find out if their exists similar differences between high yielding dwarf indicas currently under cultivation in different parts of India and the old tall varieties. The objective of this study were therefore:

1) to find out the differences between the high yielding dwarf varieties and tall varieties with respect to carbohydrate content of the various plant parts at different growth stages as affected by nitrogen manuring,

2) to study the pattern of distribution of carbohydrates in the forms like, reducing sugar, non reducing sugar, total soluble sugar, starch and total carbohydrates in various plant parts and correlate them with carbohydrate metabolism of the plant as a whole and

3) to study the correlation between some morphological features and carbohydrate metabolism of the plants.

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CHAPTER-II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

1. Carbohydrate metabolism in different organs of the rice plant :

The rice plant can be conveniently divided into the following organs. The leaf blade, the leafsheath, the culm and the panicle.

Murayama (1965) suggested the following functions of the different organs of the rice plants. The leaf blade is an organ with a high content of protein and mineral nutrient in which photosynthesis is vigorously carried out. The culm is an organ that stored temporarily the surplus product of photosynthesis. The leafsheath stores the surplus product of photosynthesis in the form of starch and functions intermediate in character between those of the blade and the culm. The ear is the storage organ and accumulates not only the photosynthates after heading, but also carbohydrates, protein and some nutrients such as nitrogen, phosphorous, magnesium and sulphur.

According to Togari _et al_ (1954) and Murayama _et al_ (1955) the behaviour of carbohydrate and nitrogen at successive growth stages of the rice plant varies markedly among the organs.

Carbohydrate metabolism in the vegetative parts
(leaf blade, leafsheath and culm) :

Togari, Okamoto and Kumura (1954) studied the behaviour of starch grains in various organs of the rice plant. They observed that immediately after transplanting the percentage of nitrogen in each of the plant organs were comparatively low, much starch was accumulated in leafsheath and in culm. At the time of vigorous tillering stage, the percentage of Nitrogen was the highest in each organ but percengage of starch was found to be very low. From the period of earprimordia formation to the beginning of ripening, nitrogen content of each organ diminished rapidly and starch was accumulated in the culm and the leafsheath. About two weeks previous to heading, the panicle commenced a rapid development during which nitrogen content of the leaf decreased. As ripening progressed starch content in the culm and the leaf sheath was reduced but increased in the panicle.

The carbohydrate metabolism in the vegetative organs of rice-plant with growth has been discussed by Nagai (1959). According to him at the earlier stages of growth of rice plant the chlorophyll content in leaf is high, the activity of catalase is vigorous, those of invertase and amylase which are closely related to translocation of photosynthates are similarly vigorous. The carbohydrate content is not great nor rich in soluble fractions. Photosynthates are translocated activitely to the growing parts and consumed for the developments of various plant organs. Upon entering the next stage of growth that is from the period of young ear development to its completion which may last about a month, activities of amylase and invertase are some what quickened, photosynthetic activities may be kept high or may be more vigorous than in the previous period in which nitrogen accumulation has been vigorous. The carbohydrate component rapidly increases, photosynthates are accumulated in the leaves and culm and the building materials of cell wall, cellulose and lignin are also accumulated vigorously. Arriving the heading and flowering stages chlorophyll concentration decline and vigorous-catalase activities are replaced by the stronger amylase and invertase activities. Carbohydrate commence translocating from the leaf to the developing panicle. On reaching the maturity stage after flowering plant activities are characterised by accumulation of starch in the grain. Photosynthates in the leaves, culm are translocated actively into the panicles.

Recently C^{14} has been used by some workers to study carbohydrate metabolism in the rice plant.

From the studies conducted at IRRI (1964) following conclusions have been drawn about carbon assimilation in the rice plant.

a) A large portion of C^{14} assimilated at any particular stage of growth is taken into the organ developing at that time.

b) The proportion of fixed CO_2 subsequently lost by respiration is quite large generally not less than 50%.

c) Fixed C^{14} administered at the early growth stages is translocated to developing organs, becomes a component of cell wall and is not retranslocated. The amount in this category may be about 50% of the total assimilated at the early growth stages, 40 to 50% during panicle development and only 10% after flowering.

d) Translocation into the grain may amount only to 2% of the C^{14} fixed at the early growth stages, 5 to 10% during panicle development and 30 to 50% after flowering.

Shen and Tanaka (1967) also used $C^{14}O_2$ to study carbohydrate metabolism in rice plant at different growth stages. The plants were exposed to $C^{14}O_2$ at 3 growth stages i.e. 40 days after transplanting, the booting stage and milky stage. They observed that carbon assimilated at 40 days after transplanting was distributed mostly to the lower leaves. At booting stage 13% of C^{14} was found in husks and 6 to 10% in the brown rice at harvest. Of the total C^{14} assimilated 45% was retained in the plants at maturity and 55% was consumed by respiration. At the milky stage 32% of C^{14} accumulated in grain. The carbon accumulated as carbohydrate, in the leafsheath and culm before flowering was re-allocated to the panicle after flowering. It was shown that 35 to 60% of assimilated carbon was consumed through respiration.

From the above studies using C^{14} and from the studies conducted in other workers (Ishizuka and Tanaka, 1952, Murayama et al, 1955, Takeda, 1960) it can be concluded that the carbon contents of the grain in rice plant is derived from the photosynthetic products originating in the leaves after the flowering stage.

According to Oshima et al (1960) starch accumulated in the vegetative parts before flowering serves as a buffer, for unseasonable condition in the early stages.

Of all the leaves of the rice plant the top leaves contribute most heavily to the formation of grain as indicated by the experiments of Fujiwara and Suzuki (1957) and Tanaka (1958).

Kasai and Asada (1965) observed that the translocation of photosynthetic products from the top leaf to the grain was more active than that to lower leaves. Within 5 hours after assimilation 15% of the C^{14} of the total amount fixed was detected in grain.

Sucrose is considered to be the primary product of photosynthesis in rice and also main form in which carbohydrates are translocated (Asada et al 1960).

Kasai and Asada (1965) observed that within 5 hours of C^{14} assimilation by top leaves of rice plant, sucrose was the main form of carbohydrate which was present on the route of translocation i.e. in the leafsheath, node and stem.

Akazwa (1965) also concluded "that in cereals carbohydrates are translocated in the form of sucrose which is the initial product of photosynthesis".

The mechanism of starch synthesis in leaves has been investigated by a limited number of investigators who studied starch synthesis in chloroplasts.

Akazwa (1965) suggested that in the chloroplasts of many plants ATP probably directly participated in starch formation through ADPG synthesis and subsequent transglucosylation reactions.

Nomura et al (1967) concluded from their studies of starch biosynthesis in chloroplasts of rice seedlings that the major metabolic pathway for UDPG utilization, appear to be synthesis of either sucrose or sucrose phosphate. They also observed a specific precursor role of ADPG for synthesising chloroplast starch by the ADP-glucose-starch-transglucosylation reaction.

2. Carbohydrate metabolism in the grain :

Carbohydrate metabolism in rice grain at different periods after flowering has been studied by a number of workers.

Ueda, Shimizu and Ota (1953) studied synthesis of amylose and amylopectin in the rice grains after flowering and observed that amylopectin was formed in the grain in the early stage of maturity.

Aimi (1956) studied the change in starch, sugar and starch synthesising enzyme in rice grain at different stages of its development. He observed that starch increased rapidly from 7th to 20th day and reached a maximum by 30th day after fertilization. Sugars increased upto the 15th day and then decreased rapidly. The amount of phosphorylase in the endosperm increased rapidly to the 18th day and disappeared after the 30th day. The stage of starch formation coincided with the period of greatest phosphorylase activity and of reduction of inorganic phosphorus (which inhibits phosphorylase activity). The quantity of rice-amylase was very small in early stages but later increased and reached a maximum after the 20th day of fertilization.

Danjo (1965) studied carbohydrate metabolism in ripening and germinating rice seed and observed that during ripening the quantity of sucrose appeared early and remained constant in the embryo while in the endosperm it was high for the first 25 days and then leveled off. Glucose and fructose in the endosperm disappeared within 25 days. Raffinose present in the embryo only was dectectable 15 days after flowering.

Studies conducted at IRRI (1966) in developing grains of IR. 8 indicated the presence of starch granules in four days old grains (after flowering). These compound starch granules were found to be loosely packed in the peripheral cell especially in the ventral area. As the grain developed, dry matter, starch and protein increased but leveled off 4 weeks after flowering. The starch granules were found to be loosely packed in the peripheral cell especially in the ventral area. As the grain developed, dry matter, starch and protein increased but leveled off 4 weeks after flowering. The starch granules progressively increased in size during ripening and reached a mean granule size of 6.3 micron in the mature caryopsis.

Baun, Palmiano, Perez and Juliano (1970) determined the levels of starch, soluble sugars and enzymes involved in starch metabolism such as α-amylase, β-amylase, phosphorylase, Q-enzyme, R-enzyme and starchsynthetase in the developing rice grain of the variety IR. 8. They observed that phosphorylase, Q-enzymes and R-enzyme had peak activities 10 days after flowering whereas α and β amylases had maximal activities 14 days after flowering. Starch synthetase bound to starch granules increased in activities upto 21 days after flowering.

Kono and Ohashi (1970) investigated the localisation and properties of polysaccharides at various stages of seed development from flowering to the 7th days in Japonica and indica varieties. They observed that 3 days after flowering amylose like polysaccharides were found to be localised in the inner integuments and funicles and epidermis of the nucleus. A large amount of polysaccharide was found in the endosperm tissues.

The mechanisms of starch biosynthesis in rice grain has been a subject of controversy since long.

According to Aimi (1956) phosphorylase is the main starch synthesising enzyme in the rice plant. He observed that the stage of starch formation in rice grain coincided with the period of greatest phosphorylase activities. The organic phosphorus level which inhibits phosphorylase activity was low, at the period of highest phosphorylase activity and the pH was 6 or more which was favourable for synthesis of starch by phosphorylase.

Kuraswa et al (1959) isolated phosphorylase from rice seeds at the milky stage and observed that the enzyme could synthesised starch from glucose-1-phosphate without addition of any primer.

Hamada (1961) isolated phosphorylase from rice plant, and synthesised starch with this enzyme. He also studied the seasonal changes in activities of phosphorylase, Q-enzyme and amylase in rice plant. He observed that the starch content of all the rice varieties studied increased parallel to phosphorylase activities. Q-enzyme activity changed parallel to the phosphorylase activity. The amylase activities were low and increased slowly during the ripening stage.

Igaue and Kuraswa (1963) studied the mode of action of Q-enzyme in grains of glutinous and nonglutinous varieties. They could not find any difference in the activity of this enzyme among these varieties.

Leloir and his associates (Leloir and Cardini 1957, Leloir *et al* 1959, Leloir and Goldemburg 1960) discovered a new enzyme mechanism of glycogen biosynthesis involving UDPG (Uridin diphosphate glucose) and subsequently they extanded their study to starch biosynthesis (De Fekete *et al* 1960, Leloir *et al* 1961) using bean, sweetcorn and potato enzymes and established the operation of the mechanism.

$$UDPG + acceptor(G)_n \longrightarrow UDP + Starch(G)_{n+1}$$

Murata *et al* (1963) isolated adenosin diphosphateglucose (ADPG) from ripening rice grains and suggested that starch synthesis was effected from ADPG by an enzyme bound to starch granules in the rice grain.

Murata *et al* (1964) (a) reported that ADPG and UDPG could be synthesised by crude rice grain enzymes by phosphorylation reaction.

$$Glucose\text{-}1\text{-}PO_4 + ATP\ (UTP) \rightleftharpoons ADPG(UDPG) + Pyrophosphate$$

and by the reversal of ADPG (UDPG) sucrose transglucosylation reaction.

$$Sucrose + ADP(UDP) \rightleftharpoons ADPG\ (UDPG) + Fructose.$$

Murata *et al* (1964 b) established the dominance of ADPG path way over UDPG pathway in starch biosynthesis in the rice grain. They observed that 80% of glucosyl unit were transferred from ADPG to the starch molecule during two hour incubation period but only 1/3rd of this amount was transferred fron UDPG during this time. It was further shown that the glucose transfer through the ADPG pathway largely went into the amylopectin fraction while that of UDPG transferred about equally in the amylose and amylopectin fraction.

Akazwa (1965) discussed two possible mechanism by which starch could be synthesised in rice grain.

I) (Sucrose) $\xrightarrow{\text{invertase}}$ (glucose +fructose) $\xrightarrow[\text{ATP}]{\text{Hexokinase}}$

(glucose -6- phosphate
fructose-6- phosphate) ⟶ (glucose 1-phosphate) $\xrightarrow[\text{(ATP or UTP)}]{\text{Pyrophosphorylase}}$ (ADPG or UDPG)

STARCH $\xleftarrow{\text{Starchsynthetase}}$ (ADPG or UDPG)

II) (Sucrose) $\xrightarrow[\text{(ADP or UDP)}]{\text{Sucrose synthetase}}$ (ADPG or UDPG)

(Starch) $\xleftarrow{\text{Starch synthetase}}$ (ADPG or UDPG)

Since sucrose is the form in which carbohydrates are translocated in rice plant, the second mechanism involving sucrose-starch conversion is important.

Tanaka, Asada, Kasai (1967) studied sucrose starch conversion in rice grain and concluded that starch was mainly synthesised directly from sucrose through ADP-glucose or UDP-glucose.

3. Carbohydrate metabolism as related to nitrogen responsiveness of rice varieties.

Most of the earlier studies with respect to metabolism of the rice plant as related to its nitrogen responsiveness were carried out by Japanese workers. They mainly studied carbohydrate or nitrogen metabolism of high nitrogen responsive *japonica* varieties as compared to low nitrogen responsive _indica_ varieties, since high nitrogen responsive indica varieties were not available until the development of varieties like TN-1 and IR.8.

Takahashi, Iwata and Baba (1959) compared 3 varieties differing in their nitrogen response and observed that in low nitrogen responsive varieties there was a higher rate of nitrogen absorption in the early growth-stages, which resulted in vigorous growth and less accumulation of carbohydrate in leaf sheath and culms.

Yamada (1959) compared some _japonica_ and _indica_ varieties and concluded that the _indica_ varieties were able to produce more dry matter than _japonica_ varieties. However the _japonica_ varieties were able to utilise 50% of total dry matter in grain production whereas the indica varieties utilised less than 40% of total dry matter for the same purpose. They described following physiological causes for the low rate of distribution of dry matter to grains. Nitrogen absorption is possibly high but in the process of nitrogen assimilation, large quantity of the photo-synthetic product such as glucose is consumed. Glucose is utilised to produce cell-wall substance such as cellulose, hemicellulose etc. The result is that there is luxuriant growth of vegetative organs and depression in accumulation of starch before heading as well as low production of starch after heading.

Baba (1961) compared four different varieties differing in their nitrogen response and observed that low nitrogen responsive varieties absorb much more nitrogen at the early growth stages and make greater growth and leaf area development in the high responsive varieties. Most of the photosynthetic product is utilised to form cell-membrane substances (cellulose and lignin). Leaving only a small portion of carbohydrate to be stored in the smaller degree of lowering of grain/straw ratio by heavy manuring in high responsive varieties that the accumulation of carbohydrate and the translocation of it to the panicle might be greater with high responsive varieties. In low nitrogen responsive varieties he observed greater decrease in starch content of leaf sheath + stem under heavy application of nitrogen.

Bredero (1965) studied the nitrogen response mechanism of indica variety BG-79 and arrived at similar conclusion as Baba with respect to lower carbohydrate storage in indica varieties at earlier growth stages.

Tanaka (1965) compared a japonica variety Tinan-3 with an indica variety Peta and observed that Tinan-3 had higher carbohydrate content than Peta at the earlier growth stages. However at flowering Tinan-3 had low carbohydrate content than the other varieties. The carbohydrate content at the early stages of growth of Peta was lower in the rainy season than in the dry season and that at the flowering stages was far higher in the former than in the latter. The fluctuation in the carbohydrate content in the "Peta" in the dry season during growth was similar to that of Tinan-3. The higher carbohydrate content Tinan-3 at earlier growth stages indicated that this variety could store a part of the assimilated energy as starch instead of using it for nitrogen uptake and expansion of plant size. A lower carbohydrate content at the flowering stage of the variety indicated that a large proportion of starch that accumulated in the grain during ripening was the assimilated product after flowering.

Murata (1965) discussed two possibilities for the lower accumulation of starch in low nitrogen responsive varieties. (i) Low responsive varieties are inferior in their capacity to produce carbohydrate or (ii) although they are not inferior in carbohydrate production they consume more carbohydrate in the growth of plant parts other than ears theirby decreasing the amount of starch to be stored. He however concluded from his earlier studies (Osada and Murata 1962 a, 1962 b) that the first one was largely responsible for differences in nitrogen response.

The carbohydrate metabolism of a high nitrogen responsive indica variety IR.8 as compared to some low nitrogen responsive indica varieties has been recently studied at IRRI (1967). Heavy application of nitrogen lowered the total sugar and starch content in the leaf sheath + culm of the low nitrogen responsive varieties to a greater degree than IR.8. The varietal difference in carbohydrate accumulation as affected by nitrogen application was more marked in starch than in total sugar. A close relationship was observed between the starch content of the plant at a high nitrogen level and plant type. It was concluded that a high nitrogen level could be used as a biochemical parameter for the high nitrogen responsiveness of rice varieties. The above study also indicated that in improved varieties such as IR.8, more than 80% of the grain starch comes from photosynthesis after flowering.

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CHAPTER-III

MATERIALS AND METHODS

MATERIALS AND METHODS

A potculture experiment was conducted with two high yielding varieties, IR.8 and Jaya and two tall varieties PTB. 10 and BBS. 2 during rabi season of 1970-71. The experimental details are given below:

M A T E R I A L S :

Soil :

Soil used in the experiment was a surface soil (0-6") and was collected on 5th January, 1970 from a cultivated field of village Bharatipur under Pipili Block of Puri District. The village is situated in the deltaic alluvial region of Orissa. The soil was air dried, powdered and passed through a 2 mm. sieve. About one kg. of soil was kept separately for the physical and chemical analysis. Result of the soil analysis are presented in Table-1.

Table-1
Physical and chemical analysis of soil

i.	Mechanical analysis :			
	a. Coarse sand	...	45.74	78.24%
	b. Fine sand	...	32.50	
	c. Silt	...	12 %	
	d. Clay	...	9.76%	
ii.	Textural class	...	Sandy loam	
iii.	Total Nitrogen	...	0.045 %	
iv.	Available K_2O	...	220 kg/ha.	
v.	Available P_2O_5	...	35.5 ppm = 71 kg/ha.	
vi.	Organic carbon	...	0.90 %	
vii.	pH	...	4.75	
viii.	C.E.C.	...	2.745/me/100 gm soils	

Seeds :

The seeds of the high yielding and tall varieties were collected from the Department of Botany of the College. Seedlings were raised in glazed pots in the green house. 25 days old seedlings were used for transplanting.

The varietal characters as available from the Department of Botany about the four varieties used in this study are presented in Table-2.

Table-2
Some of the varietal characters of rice varieties.

Variety	Parentage	Maturity duration Rabi	Maturity duration Kharif	Plant height cm.	Panicle length	1000 grain wt.	Remarks
Jaya	TN 1 x T 141	145	130	81.6	22.0	26.4	Suceptible to bacterial blight, long and bold grain.
IR. 8	Peta x Deegeowoogen	150	135	84.6	22.0	27.4	-do-
PTB.10	Selection from Thavalkannon	145	130	105	18.10	23.480	Tall stout plant resistant to bacterial blight.
BBS.2	Selection from local varieties	140	135	140	20.2	24.32	Deep rooted crop drought resistant.

Fertilisers :

Nitrogen :

Chemically pure urea (B.D.H.) was used as the nitrogenous fertiliser. Nitrogen was applied to the pots at three levels.

a) 30 kg N/hectare.

b) 60 kg N/hectare.

c) 120 kg N/hectare.

Phosphorous and Potash :

Phosphorous in the form of KH_2PO_4 was applied to all the pots at the rate of 50 kg of P_2O_5/hectare. Potasic fertiliser was not applied to any pot, except that it received from KH_2PO_4 along with P.(about 33 kg K_2O/ha)

2. DETAILS OF POT CULTURE EXPERIMENT :

Glazed pots having 10 kg. capacity were cleaned properly and the holes were closed by rubber corks to avoid leaking. 8 kg of soil were taken in each pot. Fertilisers were applied to each pot as a basal dose in the form of aqueous solution. 25 day old seedling's four in number were transplanted in each individual pot. After 20 days two seedlings were uprooted and burried in the same pot.

The usual cultural practices were adopted throughout the experiment. No pesticides were used. In the case of insect attacks insects were hand picked and killed.

3. EXPERIMENTAL DESIGN :

Experiment was laid out in a completely randomised design, with two replications. Each replication consisted of 12 treatments i.e. 4 varieties at 3 levels of nitrogen. In each treatment there were 5 pots. One pot was removed during each of the 5 stages of sampling.

Other experimental details are given below.

Varieties :

V_1	..	Jaya
V_2	..	IR. 8
V_3	..	PTB. 10
V_4	..	BBS. 2

Nitrogen - 3 levels.

N_1	..	30 kg of N/hectare.
N_2	..	60 kg of N/hectare.
N_3	..	120 kg of N/hectare.

Number of replications - 2.

Sampling stages .. 5.

4. SAMPLING TECHNIQUE :

Samples were taken during the following stages of growth.

1. Vegetative stage .. 30 days after transplanting.
2. Booting stage .. 3-4 days before flowering.
3. Early milky stage .. 7 days after flowering.
4. Mid milky stage .. 14 days after flowering.
5. Mature stage .. Harvesting stage.

For the vegetative stage the sampling was done on the same date, for all the varieties. However, from the booting stage onwards, sampling was done in different dates for different varieties, as the four varieties came to these stages at different time. The sampling time from booting stage onwards was fixed by external appearances of the plants.

In each sampling day both the plants of a pot were removed from above the soil surface with the help of a sharp knife.

The sampled parts were taken to the laboratory where the base of the plants were washed properly by the help of distilled water. After washing, the excess water was wiped out gently by the help of a filter paper. The following plant parts were sampled for study.

1. Leaf : Leaf blades only.

2. Stem : The entire plant excluding the leaf blades and panicles.

3. Grain : Rice seeds with husks.

The separated plant parts were weighed quickly and then cut into small pieces. A weighed amount of the parts was immersed in hot boiling alcohol which was taken in a conical flask. Every effort was taken to reduce to a minimum the time taken from the removal of the plants from the pots to putting the plant parts in the hot alcohol.

The mouth of the flasks were closed by the help of polythene pieces and they were stored in a refrigerator. A portion of the plant parts was weighed simultaneously into a moisture box for determination of moisture.

CHEMICAL ESTIMATIONS :

Total carbohydrate :

The different plant parts which were taken for the determination of moisture were powdered and passed through 80 mesh sieve. 200 mg of powdered plant samples were taken in a pyrex tube and 5 ml of 0.7 (N) HCl was added to it. The tube was covered loosely by a glass stoper and placed in a boiling water bath for 2½ hours. The contents of the tube were then cooled neutralised with 5 (N) NaOH and filtered. To the filtrate one ml of saturated neutral solution of lead acetate was added. The solution was again filtered into a beaker containing sodium oxalate. A white ppt was formed in the beaker. A few more drops of sodium oxalate solution was added to see that lead was completely precipitated. The ppt. was filtered and the clear filtrate was made up to a volume of 25 ml. Reducing sugar was estimated in this solution by the Shaffer - Somogyi method as described in A.O.A.C. (1965).

Shaffer - Somogyi's method :

5 ml of the aliquot was taken in a pyrex tube and to it 5 ml of Shaffer - Somogyi carbonate. 50 reagent was added. The tube was covered loosely by a glass stoper and placed in a boiling water bath carefully without any agitation. The tube was kept in boiling water for 15 minute. The tube was removed carefully without agitation to a wire basket and it was placed in running water for 4 minutes.

The glass stoper was removed carefully and 2 ml of (KI - $K_2 C_2O_4$) Iodide - oxalate solution and 3 ml of 2(N) H_2SO_4 was added carefully to the tube. The tube was placed in cold water bath for 5 minutes and mixed thoroughly so that all Cu_2O was dissolved. The contents of the tube was titrated with 0.005 (N) $Na_2S_2O_3$ (Sodiumthiosulphate solution) using starch as an indicator. Blank titrations were done in duplicate with each set of estimation where 5 ml of distilled water was clarified with lead acetate and lead was precipitated with sodium - oxalate. Finally all the steps of Shaffer - Somogyi's method were gone through and the resulting solution was titrated against 0.005 (N) sodium thiosulfate. The difference between the blank value and the sample value was used to calculate the amount of reducing sugar from a standard curve.

Standard curve for reducing sugars :

A number of standard solutions were prepared with A.R. grade dextrose. All the solutions were clarified with leadacetate and then lead was precipited with sodium oxalate as described before. The final volume of the solutions were adjusted so that they gave concentrations of 0.2 mg ------ 1.8 mg of dextrose for 5 ml of the solution.

5 ml of each of the standard solutions were taken in separate pyrex tubes. 5 ml of distilled water was

taken in two of the pyrex tubes. To each tube Shaffer - Somogyi carbonate 50 reagent was added and the procedure described before was followed. The differences between the blank and the titration value of the different standard solutions were ploted against concentration of reducing sugar in 5 ml of the solutions. The amount of reducing sugar present in the plant extracts was estimated using the above standard curve.

Alcohol soluble carbohydrate :

The sample which were kept in 80% alcohol were homogenised in a waring blender for 2 minutes and then filtered through two layers of muslin using a filter pump. The residues left on the muslin was transferred to the blender and homogenised for the second time with 80% alcohol. The homogenate was filtered through the same muslin used before, with suction. The combined filtrate from both the filtrations was taken in a 250 ml volumetric flask and made upto the volume with 80% alcohol. The volumetric flask was stored in a refrigerator.

25 ml of clear alcoholic extract were evaporated in a "flash evaporator" to drive off the alcohol. The alcohol free extracts were used for the estimation of reducing, non reducing, on total soluble sugars.

Estimation of reducing sugar :

The alcohol free extract was taken in a beaker and placed in boiling water bath for 3 minutes. Then it was cooled clarified with neutral lead acetate and made free of lead with sodium-oxalate as described under estimation of total carbohydrates. Reducing sugar was determined by the Shaffer - Somogyi's micro method using the standard curve prepared under the estimation of total carbohydrate.

Estimation of total soluble sugar :

10 ml of the clarified solution prepared for the estimation of reducing sugars were taken in a 100 ml beaker and to it 5 ml of 6 (N) HCl was added. The beaker was covered by a watch glass, and placed on a boiling water bath at 60°C for 10 minutes. The beaker was stirred occasionally. The beaker was cooled to room temperature and neutralised with 5 (N) NaOH using bromocresol green as an indicator. The acid colour of the indicator was adjusted by using 2 (N) H_2SO_4. The volume was made upto 25 ml. 5 ml of this solution was used to determine reducing sugar by the method followed in total carbohydrate estimation.

Standard curve for non reducing sugar :

A separate standard curve was used for estimation of non reducing sugar. Standard solutions of sucrose (A.R.,B.D.H.) were hydrolysed in the similar way as the samples, neutralised and reducing sugar in the hydrolysates were determined exactly in the same way at described for total carbohydrate. A standard curve was drawn with ml of sodium thiosulphate in X-axis and concentration of reducing sugar in 5 ml of the hydrolysate in the Y-axis.

Estimation of non reducing sugars :

Non reducing sugar was calculated by substracting reducing sugar from total soluble sugar.

Non reducing sugar = Total soluble sugar - reducing sugar.

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CHAPTER-IV

RESULTS

AND

DISCUSSION

RESULTS AND DISCUSSION

The results described in the following pages are from a potculture experiment, which was conducted during rabi season of 1971. The crop growth was normal and the climatic condition was not different from other years. Total carbohydrate, soluble carbohydrates, reducing and non reducing sugars were determined in the various plant parts at different growth stages. A number of growth characters of the four rice varieties used in this study were also observed. As described before (page 20) the four rice varieties included two high yielding varieties IR. 8 and Jaya and two tall varieties, PTB. 10 and BBS. 2. The nitrogen levels at which they were grown were 30, 60 and 120 kg N/hectare.

Effect of nitrogen manuring on some growth characters :

The growth characters studied at 3 Nitrogen levels and at different growth stages were as follows:

1. Weight of leaves.
2. Weight of Stem.
3. Leaf/stem ratio.
4. Weight of straw.
5. 1000 grain weight, 1000 kernel weight and grain/kernel ratio.

LEAF WEIGHT :

The oven dry weight of leaves expressed as gm/pot (two plants) are given in table - 3.

Table-3 a.
Weight of leaves (g/pot) at vegetative stage (30 days after transplanting)

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	1.95	2.80	3.90	2.88
IR. 8	1.85	2.75	3.80	2.80
PTB. 10	2.45	3.05	3.85	3.12
BBS. 2	2.35	3.15	4.20	3.23
Nitrogen mean	2.15	2.94	3.93	

Table-3 b.
Weight of the leaf (g/pot) at bootleaf stage

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	3.75	4.80	5.85	4.80
IR. 8	2.90	4.90	6.50	4.77
PTB. 10	1.75	2.55	3.70	2.67
BBS. 2	1.90	3.10	5.73	3.85
Nitrogen mean	2.57	3.84	5.44	

Table-3 c.
Weight of leaves (g/pot) at early milky stage

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	2.74	3.40	6.32	4.15
IR. 8	3.28	5.67	6.90	5.28
PTB. 10	1.65	2.58	4.29	2.84
BBS. 2	2.67	3.89	4.15	3.57
Nitrogen mean	2.58	3.88	5.60	

Table-3 d.
Weight of leaves (g/pot) at mid milky stage

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	3.32	4.19	5.92	4.48
IR. 8	3.80	5.27	7.51	5.53
PTB. 10	1.45	2.35	3.64	2.48
BBS. 2	4.07	2.97	7.34	4.79
Nitrogen mean	3.16	3.69	6.10	

Table-3 e.
Weight of leaves (g/pot) at harvesting stage

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	4.60	6.48	8.54	6.54
IR. 8	4.30	6.42	11.76	7.49
PTB. 10	2.00	2.99	4.43	3.38
BBS. 2	2.82	3.87	5.76	4.15
Nitrogen mean	3.43	4.94	7.62	

It is observed from the Table-3a-e that weight of leaves of the two high yielding varieties and two tall varieties at the vegetative stage (30 days after transplanting) were not much different from one another. However the differences between high yielding variety and the tall varieties became increasingly evident with the growth of the plant (Fig.1 a.).

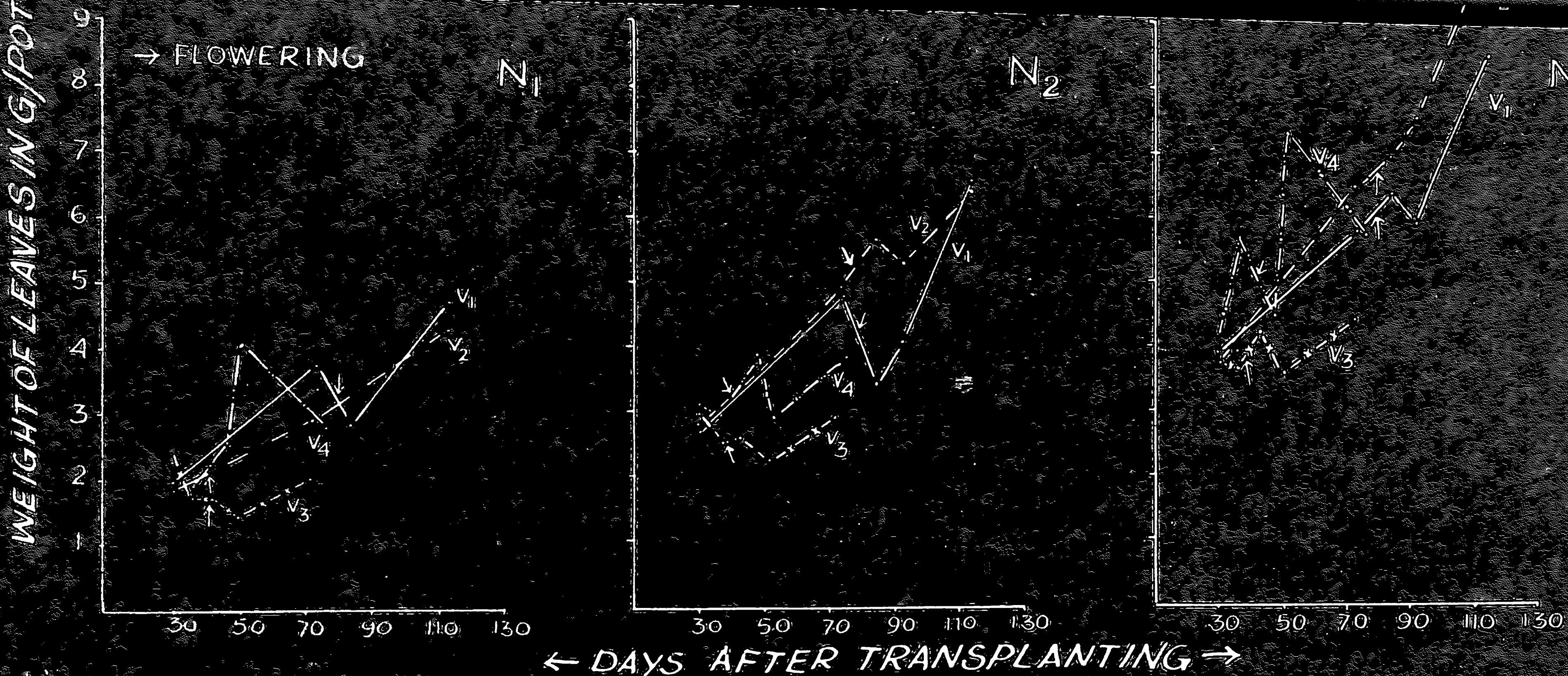
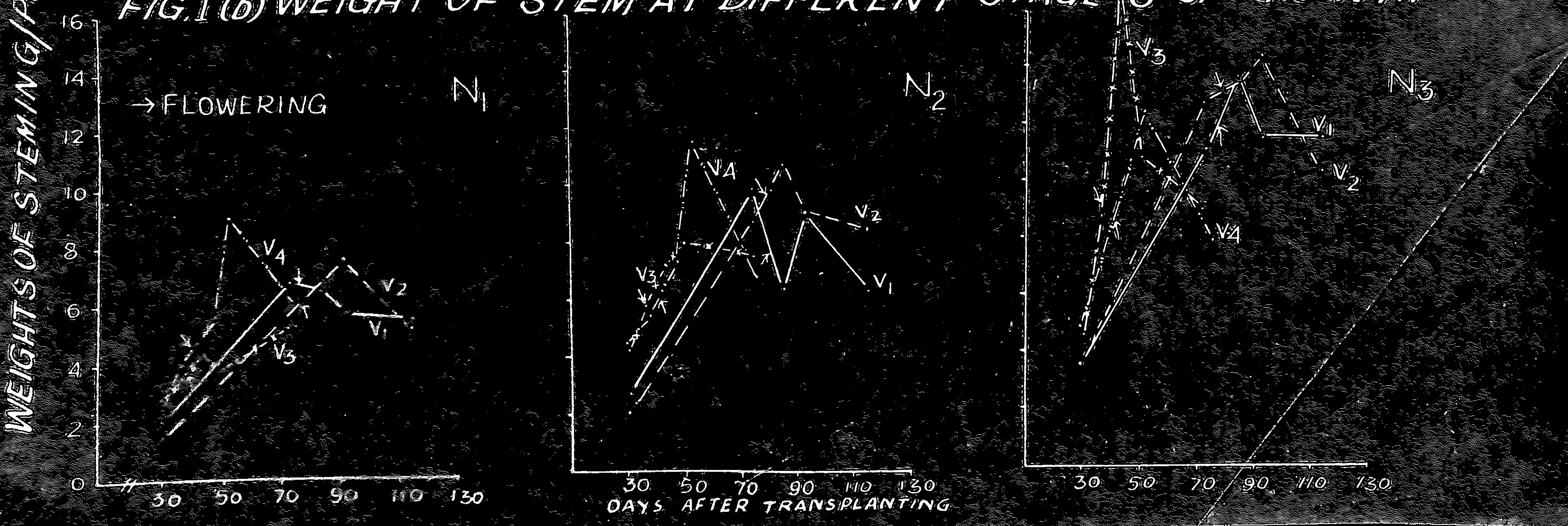


FIG.1 (b) WEIGHT OF STEM AT DIFFERENT STAGES OF GROWTH



with the increase in N application the leaf weights of the high yielding varieties increased considerably as compared to the tall varieties. The maximum differences between the tall varieties and the high yielding varieties was observed at harvest. It was also observed from (Fig.1 a) that at N_1 and N_2 levels the leaf weight of the tall varieties decreased from vegetative stage to booting stage, where as there was an increase in high yielding varieties. At N_3 levels the decrease in leaf weight from vegetative to booting stage was observed for PTB. 10 but not for BBS. 2. The leaf weight of high yielding varieties however increased considerably from vegetative to booting stage. Effect of nitrogen manuring on increase in leaf dry weight of varieties differing in their nitrogen response has been studied by Baba (1961) and Tanaka (1964). Both of them observed that the low nitrogen response varieties have more leaves at early growth stages, when there is increase in nitrogen manuring. It is observed from (Table-3a) that at the vegetative stage the leaf weight of the tall varieties were more than the high yielding varieties, at N_1 and N_2 levels, but the differences were not very much at N_3 level. The maximum difference in leaf weight was however observed at harvest (Table-3a). The observation of the Japanese worker were based mainly on comparison between japonica and indica varieties, whereas all the four varieties used in the study were indica varieties. It has already been established that the high yielding dwarf varieties IR. 8 and Jaya absorbed more nitrogen at the vegetative stage than the tall varieties (IRRI 1966)(Nayak 1970). The above observations are contrary to the findings of Baba (1961) and Tanaka (1964).

STEM WEIGHT :

The dry weight of the stems of the four varieties at different growth stages are given in Table-4-a-e.

Table-4 a.
Weight of stem (g/pot) at vegetative stage (30 days after transplanting)

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	1.99	2.77	3.72	2.83
IR. 8	1.42	1.96	3.72	2.37
PTB. 10	2.74	4.27	4.61	3.87
BBS. 2	2.37	3.45	4.81	3.54
Nitrogen mean	2.13	3.11	4.21	

Table-4 b.
Weight of stem (g/pot) at bootleaf stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	6.78	9.80	11.10	9.23
IR. 8	5.70	8.76	12.76	9.07
PTB. 10	3.57	5.80	8.85	6.07
BBS. 2	4.00	5.41	7.11	5.51
Nitrogen mean	5.01	7.44	9.95	

Table-4 c.
Weight of stem (g/pot) at early milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	6.52	6.30	13.77	8.66
IR. 8	6.75	10.16	13.57	10.16
PTB. 10	4.37	7.21	16.62	9.40
BBS. 2	5.54	7.43	10.88	7.95
Nitrogen mean	5.79	7.77	13.71	

Table-4 d.
Weight of stem (g/pot) at mid milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	5.79	9.01	11.47	8.76
IR. 8	7.46	9.01	14.38	10.28
PTB. 10	3.89	7.79	10.81	7.50
BBS. 2	0.15	11.65	12.44	11.08
Nitrogen mean	6.57	9.36	12.28	

Table-4 e.
Weight of stem (g/pot) at Maturity (Harvest)

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	5.45	6.22	11.56	7.74
IR. 8	5.32	9.41	10.30	8.34
PTB. 10	5.30	7.56	8.94	5.46
BBS. 2	6.14	6.74	7.99	6.95
Nitrogen mean	5.55	7.48	9.70	

It is observed from Table 4 as well as (Fig.1 b.) that the weights of stems of the tall varieties were more than the high yielding varieties at the vegetative stage, for all the levels of nitrogen manuring. At subsequent growth stages the weights of stems of the high yielding varieties were frequently more than the tall varieties (Table-4, Fig.1 b.). Though it is known that tall varieties have longer stems and hence give increased stem dry weight, the larger number of tillers produced by the high yielding varieties sometimes contribute to a higher stem dry weight of the high yielding dwarf varieties.

LEAF/STEM RATIO :

Leaf/stem ratio of the four varieties are given in table-5.

Table-5 a.
Leaf/stem ratio at vegetative stage (30 days after transplanting)

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	0.98	1.01	1.05	1.01
IR. 8	1.30	1.40	1.02	1.24
PTB. 10	0.89	0.71	0.83	0.81
BBS. 2	0.99	0.91	0.87	0.92
Nitrogen mean	1.04	1.01	0.94	

Table-5 b.
Leaf/stem ratio at bootleaf stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	0.55	0.49	0.53	0.54
IR. 8	0.51	0.56	0.51	0.53
PTB. 10	0.49	0.44	0.42	0.45
BBS. 2	0.47	0.57	0.80	0.61
Nitrogen mean	0.50	0.51	0.56	

Table-5 c.
Leaf/stem ratio at early milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	0.42	0.54	0.46	0.47
IR. 8	0.48	0.56	0.51	0.51
PTB. 10	0.38	0.36	0.46	0.40
BBS. 2	0.48	0.52	0.41	0.47
Nitrogen mean	0.44	0.49	0.46	

Table-5 d.
Leaf/stem ratio at mid milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	0.57	0.46	0.52	0.52
IR. 8	0.51	0.58	0.52	0.54
PTB. 10	0.37	0.30	0.34	0.34
BBS. 2	0.44	0.25	0.59	0.43
Nitrogen mean	0.47	0.40	0.49	

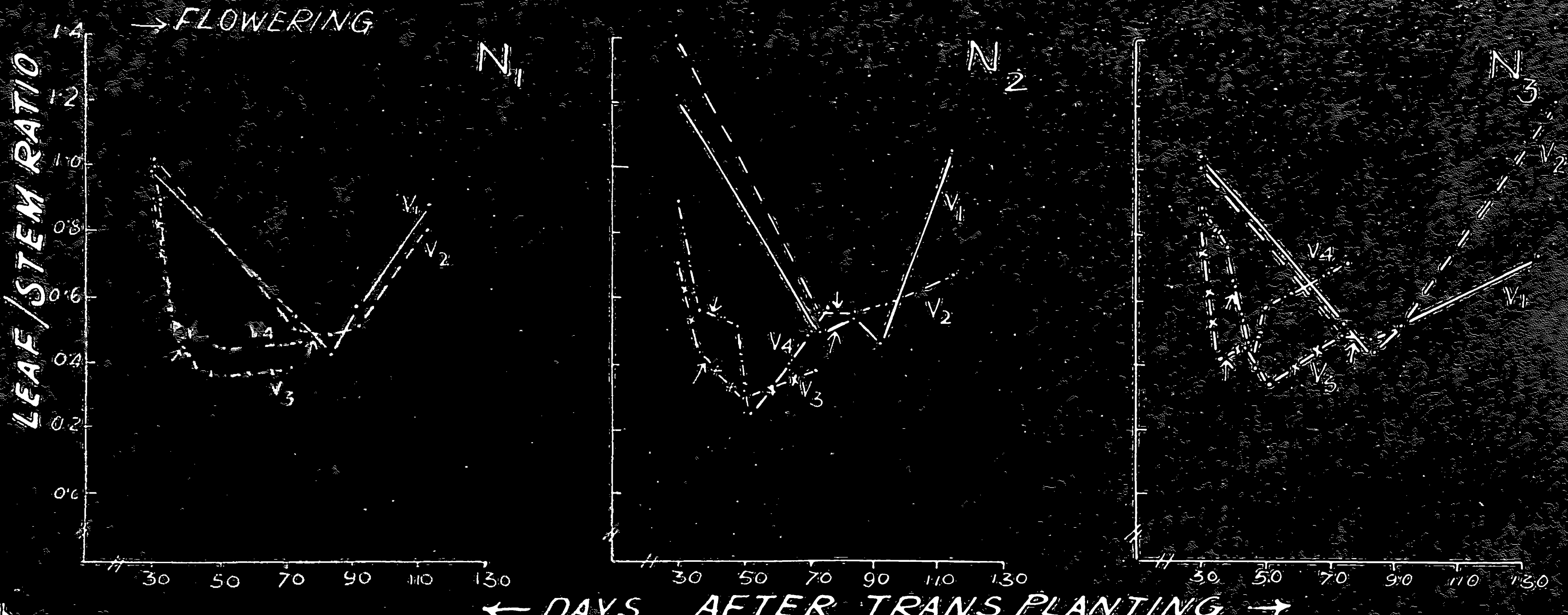
Table-5 e.
Leaf/stem ratio at Maturity (Harvest).

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	0.84	1.04	0.74	0.87
IR. 8	0.81	0.68	1.14	0.88
PTB. 10	0.38	0.39	0.49	0.42
BBS. 2	0.46	0.57	0.72	0.58
Nitrogen mean	0.62	0.67	0.77	

It is observed from the Table-5 (Fig-2 a.) that the leaf/stem ratio of all the varieties decreased from vegetative to booting stage. At the post flowering growth stages the leaf/stem ratios of the high yielding varieties increased considerably at all nitrogen levels. The leaf/stem ratio of tall varieties during post flowering stages did not improve at N_1 level. At N_2 and N_3 levels though there was increase in leaf/stem ratios of tall varieties the values were generally lower than the high yielding varieties. The ratio of photosynthetic to non-photosynthetic organ (P/N ratio) which is similar to leaf/stem ratio was determined at IRRI (1967) for two rice varieties IR. 8 and Peta at the vegetative stage (40 days after transplanting) and at flowering. It was observed at IRRI that the P/N ratios were higher at the vegetative stage but became lower after internode elongation. However IR. 8 maintained

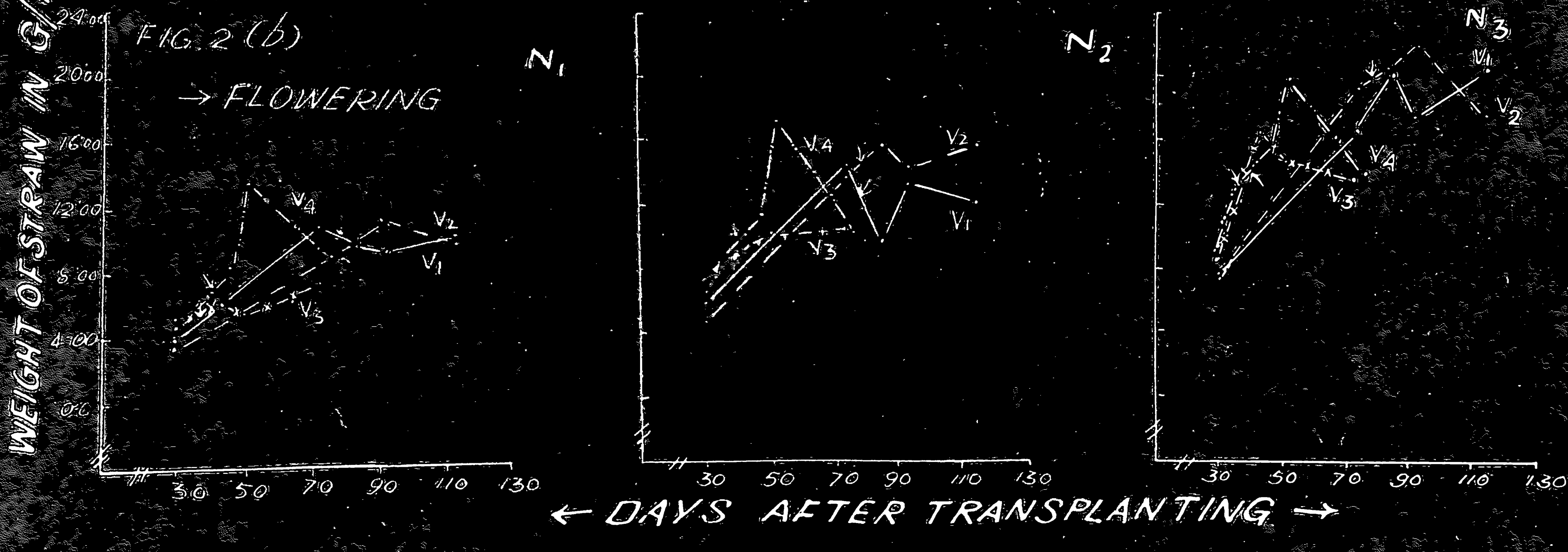
FIG. 2 (a)

LEAF/STEM RATIO



WEIGHT OF STRAW AT DIFFERENT STAGES OF GROWTH

FIG. 2 (b)



the favourable P/N ratio even after internode elongation but that of "Pota" became unfavourable. These observations are similar to the observations described above with respect to the leaf/stem ratio of IR. 8 and Jaya, as compared to PTB. 10 and BBS. 2.

STRAW WEIGHT :

The straw (leaf + stem) weight of the four varieties in different growth stages are given in the Table-6 as well as in Fig. 2(b).

Table-6 a.
Weight of straw (g/pot) at vegetative stage(30 days after transplanting)

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	3.94	5.57	7.62	5.71
IR. 8	3.27	4.71	7.52	5.17
PTB. 10	5.19	7.32	8.46	6.99
BBS. 2	4.72	6.60	9.01	6.78
Nitrogen mean	4.28	6.05	8.15	

Table-6 b.
Weight of straw(g/pot) at booting stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	10.53	14.60	16.45	13.86
IR. 8	8.60	13.66	19.26	13.84
PTB. 10	5.30	8.35	12.55	8.73
BBS. 2	5.90	8.51	12.84	9.08
Nitrogen mean	7.58	11.28	15.30	

Table-6 c.
Weight of straw (g/pot) at early milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	9.26	9.70	20.08	13.01
IR. 8	10.03	15.83	20.47	15.44
PTB. 10	6.02	9.29	16.92	10.74
BBS. 2	8.21	11.33	15.39	11.64
Nitrogen mean	8.38	11.54	14.47	

Table-6 d.
Weight of straw(g/pot) at mid milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	9.12	13.20	17.39	13.24
IR. 8	11.26	14.27	21.90	15.81
PTB. 10	5.34	10.15	14.45	9.98
BBS. 2	13.22	17.12	19.79	16.71
Nitrogen mean	9.73	13.69	18.38	

Table-6 e.
Weight of straw (g/pot) at Maturity (Harvest).

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	10.05	12.70	20.10	14.28
IR. 8	9.93	15.83	17.57	14.44
PTB. 10	7.30	10.55	13.38	10.41
BBS. 2	8.97	10.11	13.75	10.94
Nitrogen mean	9.06	12.30	16.20	

It is observed from these tables that the nitrogen manuring increased the straw weight of all the varieties substantially. At the vegetative stage (30 days after transplanting) the straw weight of the tall varieties were more than the high yielding varieties at all the levels of nitrogen manuring. At subsequent growth stages the straw weights of high yielding varieties were frequently more than the tall varieties. At harvesting stage the straw weights of the high yielding varieties were uniformly higher than the tall varieties at all the levels of nitrogen manuring.

The above results can not however be compared with the general observation (IRRI 1965, AICRIP 1968) that there is decrease in straw weights of tall varieties with the increase in nitrogen manuring. These results are mainly based on field studies where the tall varieties lodged at higher levels of nitrogen. However in the present investigation the plants grown in the pots were given adequate supports, so that they did not lodge even in the highest level of nitrogen manuring. This probably resulted in the increase in straw weights of the tall varieties with the increase in nitrogen manuring.

Table-7

Table 7 a.
Thousand grain weight (g)

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	25.25	25.91	26.49	25.88
IR. 8	24.75	24.99	26.33	25.35
PTB. 10	18.04	20.12	20.24	19.46
BBS. 2	24.38	25.81	26.30	25.49
Nitrogen mean	23.11	24.21	24.84	

	F-test	SE(m)	CD(0.05)
Variety	**	0.222	0.684
Nitrogen	**	0.193	0.594
Interaction	NS	0.386	

** significant at 1 % level.

Table 7 b.
Thousand kernel weight (g)

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	21.90	23.13	22.42	22.48
IR. 8	21.93	22.08	23.27	22.43
PTB. 10	14.22	16.42	18.20	18.28
BBS. 2	20.01	21.50	21.99	21.17
Nitrogen mean	19.51	20.78	21.47	

Table 7 c.
Grain/kernel ratio

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	1.15	1.12	1.18	1.15
IR. 8	1.13	1.13	1.13	1.13
PTB. 10	1.27	1.22	1.11	1.20
BBS. 2	1.21	1.20	1.19	1.20
Nitrogen mean	1.19	1.17	1.15	

Thousand grain weights, Thousand kernel weight and Grain/kernel ratio.

The 1000 grain weights, 1000 kernel weight and grain/kernel ratios of the four varieties at harvest are given in table 7 a,b and c.

It is observed from Table-7a that the varietal difference in 1000 grain weights was statistically significant. Nitrogen manuring increased the 1000 grain weights of all the varieties, significantly. The increase in 1000 grain weight with nitrogen manuring in case of dwarf varieties has been observed in a number of experiments conducted by AICRIP (1968-69). These experiments also indicated that 1000 grain weight in tall varieties is not affected by nitrogen manuring. In the present experiment 1000 grain weight of tall varieties appeared to increase with the increase in nitrogen manuring. As mentioned before the tall varieties were given adequate support in the pots, so that they did not lodge. This might have improved the translocation of carbohydrate to grains resulting in increase in grain weight. In lodged plants the process of translocation is seriously hampered.

The 1000 kernel weight (Table-7 b) of the four varieties also increased with the increase in nitrogen manuring and appears to follow the same trend as 1000 grain weight. The grain/kernel ratio of the 3 varieties (Table-7 c) IR.8, Jaya and BBS. 2 did not change very much with the increase in nitrogen manuring. In case of PTB. 10 there was however a continuous decrease in grain/kernel ratio with the increase in nitrogen manuring. Increased nitrogen application appears to increase its kernel weight more than the grain weight.

Effect of nitrogen manuring on the carbohydrate content of the leaves at various growth stages :

REDUCING SUGARS :

The reducing sugar content of the leaves expressed as % on oven dry weight are given in table 8 a-e.

Table-8 a.
Reducing sugar in leaf (%) at vegetative stage (30 days after transplanting)

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	0.74	1.13	1.85	1.24
IR. 8	0.74	1.03	1.64	1.13
PTB. 10	0.62	0.93	1.13	0.89
BBS. 2	0.80	1.15	1.82	1.25
Nitrogen mean	0.72	1.06	1.61	

	F-test	SE(m)	CD(0.05)
Variety	NS	0.117	--
Nitrogen	*	0.118	0.363
Interaction	NS	0.203	--

* significant at 5% level.

Table-8 b.
Reducing sugar in leaf (%) at booting stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	1.57	1.27	1.57	1.47
IR. 8	1.01	1.32	1.74	1.35
PTB. 10	1.57	1.27	1.71	1.51
BBS. 2	1.01	1.33	1.84	1.39
Nitrogen mean	1.29	1.29	1.71	

	F-test	SE(m)	CD(0.05)
Variety	NS	0.090	—
Nitrogen	*	0.078	0.240
Interaction	NS	0.157	—

Table-8 c.
Reducing sugar in leaf (%) at early milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	0.63	0.52	0.56	0.57
IR. 8	0.93	0.77	0.44	0.71
PTB. 10	0.81	0.88	1.08	0.92
BBS. 2	0.52	0.69	0.85	0.68
Nitrogen mean	0.72	0.71	0.73	

	F-test	SE(m)	CD(0.05)
Variety	NS	0.106	—
Nitrogen	NS	0.091	—
Interaction	NS	0.184	—

Table-8 d.
Reducing sugar in leaf (%) at mid milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	0.36	0.72	0.72	0.60
IR. 8	0.43	0.64	0.56	0.54
PTB. 10	1.01	0.73	0.75	0.83
BBS. 2	0.71	0.71	0.97	0.79
Nitrogen mean	0.62	0.70	0.75	

	F-test	SE(m)	CD(0.05)
Variety	**	0.040	0.123
Nitrogen	**	0.028	0.086
Interaction	**	0.058	0.178

Table-8 e.
Reducing sugar in leaf (%) at maturity (Harvest).

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	0.19	0.23	0.20	0.20
IR. 8	0.20	0.30	0.16	0.22
PTB. 10	0.38	0.42	0.37	0.39
BBS. 2	0.32	0.45	0.28	0.35
Nitrogen mean	0.27	0.35	0.25	

	F-test	SE(m)	CD(0.05)
Variety	**	0.026	0.080
Nitrogen	**	0.022	0.067
Interaction	NS	0.014	—

STAGES

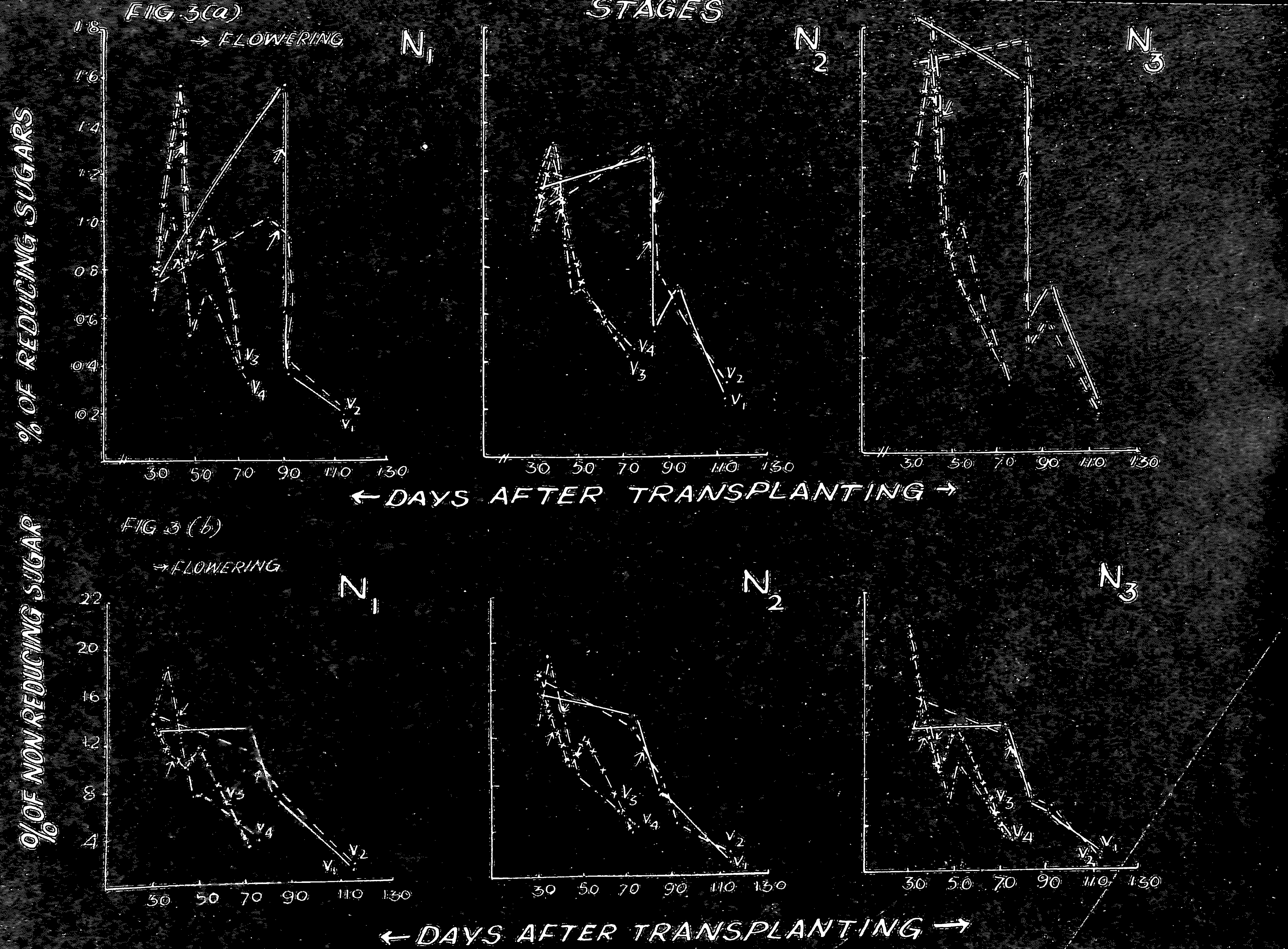
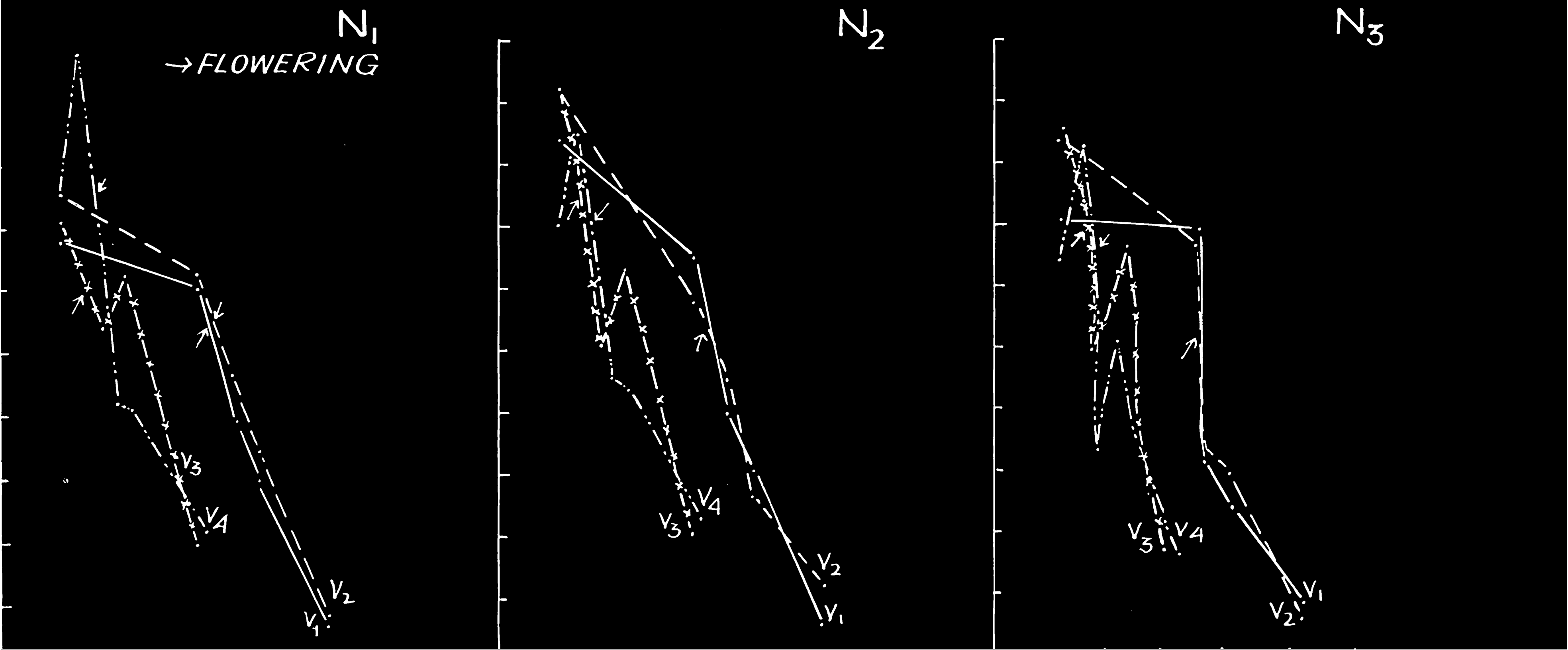


FIG 3(a)
→ FLOWERING
N1
N2
N3
% OF REDUCING SUGARS
1·8
1·6
1·4
1·2
1·0
0·8
0·6
0·4
0·2
V1
V2
V3
V4
30 50 70 90 110 130
← DAYS AFTER TRANSPLANTING →
FIG 3 (b)
→ FLOWERING
N1
N2
N3
% OF NON REDUCING SUGAR
22
20
16
12
8
4
V1
V2
V3
V4
30 50 70 90 110 130
← DAYS AFTER TRANSPLANTING →

SOLUBLE SUGAR IN LEAF AT DIFFERENT GROWTH STAGES

FIG. 4



It is observed from the above tables that the varietal differences in the reducing sugar content of the leaves were not significant at the vegetative stage, booting stage and early milky stage but became significant at mid milky stage and at harvest. The high yielding varieties Jaya and IR. 8 were found to have lower quantities of reducing sugars, in their leaves at 14 days after flowering and at harvest as compared to the tall varieties PTB. 10 and BBS. 2.

Effect of nitrogen manuring on reducing sugar content of leaves was found to be significant at all the growth stages except at early milky stage. There was in general a increase in reducing sugar content of the leaves of all the four varieties with the increase in nitrogen manuring particularly in pre-flowering stages. In the post flowering stages a reduction in reducing sugar content of the leaves of all the varieties, with increase in nitrogen manuring was frequently observed. Variety nitrogen interaction was found not be significant in any of the growth stages except at mid milky stage. At this stage the high yielding varieties were found to have significantly lower reducing sugars in their leaves, particularly at lower nitrogen level as compared to tall varieties.

The reducing sugar content of the leaves of all the four varieties at 3 nitrogen levels (except Jaya at N_3 level) were found to increase from vegetative stage to booting stage (Fig-3a). The amount of increase was found to be higher at lower nitrogen levels than at higher nitrogen levels. From booting to early milky stage, there was a sharp decline in the reducing sugar content of the leaves of the four varieties irrespective of nitrogen levels. This decline was found to be larger for the high yielding varieties than the tall varieties at N_3 levels. From early milky stage to mid milky stage some of the varieties showed a slight increase in the reducing sugar content of the leaves at certain nitrogen levels. However from mid-milky stage to harvest there was a steady decrease in reducing sugar content of the leaves of all the four varieties. At harvest the high yielding varieties had lower reducing sugar content in their leaves than the tall varieties at all the nitrogen levels; the differences being more conspicuous at lower nitrogen level.

The exact role of reducing sugar in the leaves of rice plant is not known. However glucose which constitutes the major part of reducing sugars is obtained from photosynthesis as well as from the break down of polysaccharides during the respiratory process. It has been mentioned earlier that according to many workers (Asada et al 1960) sucrose is the primary product of photosynthesis as well as the main form in which carbohydrates are translocated in rice plant. It has also been suggested (Akazwa 1965)that sucrose rather than glucose serves as a substrate for the enzymatic synthesis of starch. Thus presence of glucose in the leaves of rice plant is probably due to the respiratory break down of higher polysaccharides. It has been observed (by Baba 1961) that there is an increase in respiration with increase in nitrogen manuring. Thus the significantly higher quantities of reducing sugars found in the four varieties at higher nitrogen levels (Table-8b and Table-8c) were probably of respiratory origin, besides the usual source of photosynthesis which is also vigorous at the earlier growth stages and increases with increase in nitrogen manuring. The increase in reducing sugars from vegetative to booting stage is probably due to an increase in the activities of amylase and invertase at the booting stage as indicated by Nagai (1959). The decline in reducing sugars from booting to 7 days after flowering and finally upto harvest (Fig-3a) is due to the translocation of carbohydrates from leaves to the grains as well as due to utilisation of reducing sugars for the synthesis of cell wall materials (Nagai 1959).

NON REDUCING SUGARS :

Non reducing sugars in leaves expressed as % of oven dry weight are given in table 9.

Table-9 a.
Non reducing sugar in leaf (%) at vegetative stage
(30 days after transplanting)

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	13.09	15.83	12.29	13.74
IR. 8	14.40	17.08	15.05	15.51
PTB. 10	13.66	17.41	20.96	18.01
BBS. 2	14.50	12.88	11.09	12.82
Nitrogen mean	13.91	15.80	14.85	

	F-test	SE(m)	CD(0.05)
Variety	NS	1.302	—
Nitrogen	NS	1.105	—
Interaction	NS	2.208	—

Table-9 b.
Non reducing sugar in leaf (%) at booting stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	12.95	11.85	12.36	12.38
IR. 8	11.76	10.42	11.83	11.33
PTB. 10	11.38	14.49	13.28	13.04
BBS. 2	18.52	18.75	14.61	17.29
Nitrogen mean	13.65	13.88	13.01	

	F-test	SE(m)	CD(0.05)
Variety	NS	3.332	—
Nitrogen	NS	1.929	—
Interaction	NS	1.671	—

Table-9 c.
Non reducing sugar in leaf (%) at early milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	7.24	7.69	5.98	6.97
IR. 8	8.40	8.11	6.21	7.57
PTB. 10	10.01	9.31	8.79	9.37
BBS. 2	7.49	8.49	5.90	7.44
Nitrogen mean	8.28	8.40	6.70	

	F-test	SE(m)	CD(0.05)
Variety	**	0.406	1.251
Nitrogen	**	0.341	1.051
Interaction	NS	0.703	—

Table-9 d.
Non reducing sugar in leaf (%) at mid milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	5.64	5.47	5.06	5.39
IR. 8	6.49	4.75	5.34	5.53
PTB. 10	11.56	11.89	12.50	11.98
BBS. 2	7.61	8.18	9.32	8.37
Nitrogen mean	7.82	7.57	8.05	

	F-test	SE(m)	CD(0.05)
Variety	**	0.300	0.924
Nitrogen	NS	0.259	—
Interaction	NS	0.519	—

Table-9 e.
Non reducing sugar in leaf (%) at maturity (Harvest).

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	0.90	0.88	1.49	1.09
IR. 8	1.35	1.99	0.86	1.40
PTB. 10	3.52	3.63	3.03	3.39
BBS. 2	3.97	4.12	2.94	3.67
Nitrogen mean	2.43	2.65	2.08	

	F-test	SE(m)	CD(0.05)
Variety	**	0.293	0.903
Nitrogen	NS	0.256	—
Interaction	NS	0.502	—

It is observed from the above tables that the varietal difference in non reducing sugar content of the leaves was not significant at the pre-flowering stages, but significant at the post flowering stages of sampling. Both the high yielding variety had significantly lower non reducing sugars in their leaves at mid milky stage and harvest.

Effect of nitrogen manuring on non reducing sugar content of the leaves was not significant at any of the stage of sampling except at early milky stage. Interaction of nitrogen with the variety was not significant in any of the growth stages.

It is observed from Big-3 (b) that from booting stage onwards there was a steady and sharp decline of non reducing sugars in the leaves of the high yielding varieties up to harvest. In case of the two tall varieties there was a decline in non reducing sugars in the leaves from booting to early milky stage, but there was a tendency to increase after this stage upto mid milky stage. This tendency became more pronounced with the increase in the nitrogen manuring. From mid milky stage up to harvest, there was again a decline in non reducing sugars in the leaves of the tall varieties.

The non reducing sugars in rice plant mainly comprise of sucrose. The function of sucrose has already been discussed. It is the primary product of photosynthesis, the form in which carbohydrates are translocated and may serve as a substrate for starch bio-synthesis.

The sharp decline in the non reducing sugar content of the leaves of all the varieties from booting stage onwards was due to translocation of sucrose from the leaves to the grains.

The slight increase in non reducing sugar content of the leaves of the tall varieties from early milky to mid milky stage which became more prominent with the increase in nitrogen manuring can be explained from a consideration of supply and demand relationship. The tall varieties which produced less number of grains probably had a lower demand of carbohydrates than their leaves could supply. This resulted in a temporary increased in non reducing sugars in the leaves of these varieties. Due to higher number of grains produced by the high yielding varieties there was was a steady decline in non reducing sugars in the leaves of these varieties in the post flowering stages.

TOTAL SOLUBLE SUGARS : (Reducing + Non reducing)

The total soluble sugar content in the leaves of four varieties at 3 nitrogen level are given in the table 10 a-e.

Table-10 a.
Total carbohydrate in leaf (%) at vegetative stage(30 days after transplanting)

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	13.83	16.96	14.15	14.98
IR. 8	15.15	18.17	16.69	16.67
PTB. 10	14.29	18.35	17.09	16.58
BBS. 2	15.30	14.03	13.03	14.12
Nitrogen mean	14.64	16.88	15.24	

Table-10 b.
Total carbohydrate in leaf (%) at booting stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	14.02	13.17	13.94	13.71
IR. 8	12.77	11.70	13.58	12.68
PTB. 10	12.45	15.76	14.96	14.39
BBS. 2	19.53	17.11	16.48	17.71
Nitrogen mean	14.69	14.43	14.74	

Table-10 c.
Total carbohydrate in leaf (%) at early milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	7.88	8.21	6.54	7.54
IR. 8	9.33	8.98	6.66	8.32
PTB. 10	10.82	10.19	9.87	10.29
BBS. 2	8.46	9.19	6.75	8.13
Nitrogen mean	9.12	9.14	7.45	

Table-10 d.
Total carbohydrate in leaf (%) at mid milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	6.00	6.20	5.83	6.01
IR. 8	6.92	5.39	5.90	6.07
PTB. 10	12.82	12.63	13.26	12.90
BBS. 2	8.42	8.89	10.38	9.23
Nitrogen mean	8.54	8.28	8.84	

Table-10 e.
Total carbohydrate in leaf (%) at maturity (Harvest).

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	1.19	1.11	1.69	1.33
IR. 8	1.66	2.29	1.02	1.62
PTB. 10	3.90	4.06	3.41	3.79
BBS. 2	4.29	4.57	3.23	4.03
Nitrogen mean	2.73	2.76	2.34	

The results also are ploted in figure 4. It is observed from figure 4 that the change in total soluble sugars in the leaves of four varieties at different growth stages followed almost the same pattern as the non reducing sugars. This is due to the fact that the % of non reducing sugar was much higher than the % reducing sugars.

It is observed from the table (8,9 and 10) as well as from figure (3a, 3b and 4) that at mid milky stage and at harvest the reducing sugar, non reducing sugar and total soluble sugar content of the leaves of the high yielding varieties were significantly lower than the tall varieties at all the nitrogen levels. This can be explained from a consideration of the grain/straw ratio of these varieties. It is now conclusively known that the high yielding varieties have higher grain/straw ratio than the tall varieties. In other words a lower weight of vegetative tissues supply the nutrient requirement of a higher weight of grains in the high yielding varieties. From mid milky stage to maturity when the grain filling takes place the larger weight of the grains of high yielding varieties draw a greater quantity of soluble sugars from the leaves and in the process deplete the leaves with respect to soluble sugars. This however, does not take place in tall varieties where a higher weight of vegetative tissues supply the nutrient requirement of a lower weight of grains.

TOTAL CARBOHYDRATE (Starch + soluble sugar), starch :

The total carbohydrate and starch content of the leaves of the four varieties were determined only at 3 growth stages i.e. vegetative stage, booting stage and early milky stage. The results are presented in Tables-11a-c for total carbohydrate and Tables-12a-c for starch.

Table-11 a.
Total carbohydrate in leaf (%) at vegetative stage
(30 days after transplanting)

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	68.87	69.77	78.31	72.38
IR. 8	70.62	81.28	75.28	75.73
PTB. 10	61.12	71.46	80.47	71.02
BBS. 2	69.49	72.22	71.87	71.19
Nitrogen mean	67.52	73.73	76.48	

	F-test	SE(m)	CD(0.05)
Variety	NS	2.179	—
Nitrogen	**	1.887	5.81
Interaction	NS	3.775	—

Table-11 b.
Total carbohydrate in leaf (%) at booting stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	62.84	73.62	64.59	67.02
IR. 8	67.81	66.96	72.41	69.04
PTB. 10	72.50	69.87	75.99	72.79
BBS. 2	61.27	59.49	61.68	69.48
Nitrogen mean	66.10	66.98	68.17	

	F-test	SE(m)	CD(0.05)
Variety	**	2.402	7.40
Nitrogen	NS	2.078	—
Interaction	NS	4.157	—

Table-11 c.
Total carbohydrate in leaf (%) at early milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	75.78	72.59	68.28	72.21
IR. 8	72.31	75.59	70.71	72.87
PTB. 10	66.50	76.90	66.78	70.06
BBS. 2	74.06	70.53	69.80	71.46
Nitrogen mean	72.24	73.90	68.89	

	F-test	SE(m)	CD(0.05)
Variety	NS	1.523	—
Nitrogen	**	1.321	4.070
Interaction	NS	2.446	—

FIG. 5

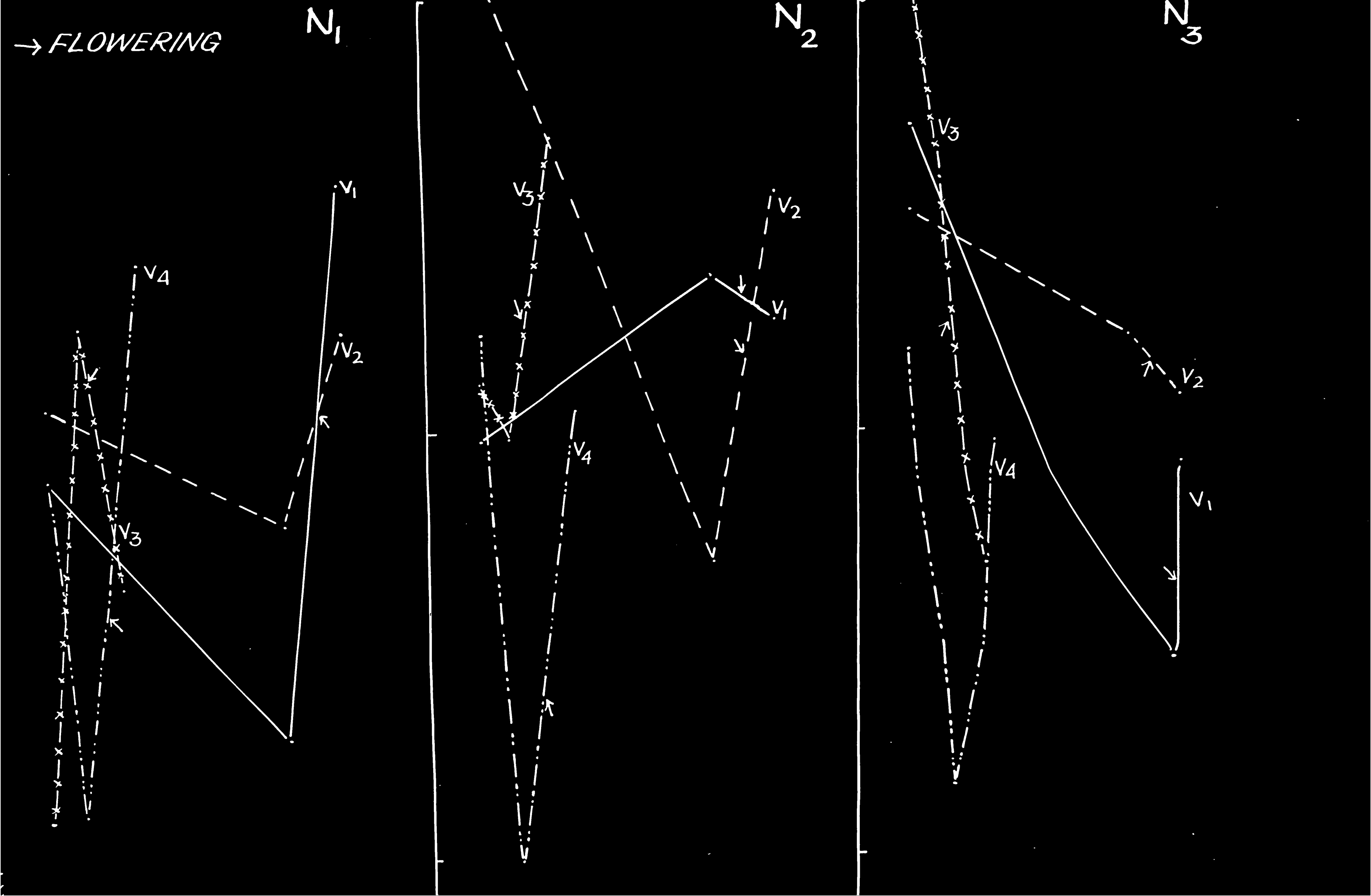


Table-12 a.
Total starch in leaf (%) at vegetative stage
(30 days after transplanting)

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	55.03	52.25	54.16	53.81
IR. 8	55.47	63.66	61.08	60.07
PTB. 10	46.83	53.12	63.37	54.44
BBS. 2	54.39	58.18	58.84	57.14
Nitrogen mean	52.93	56.80	61.86	

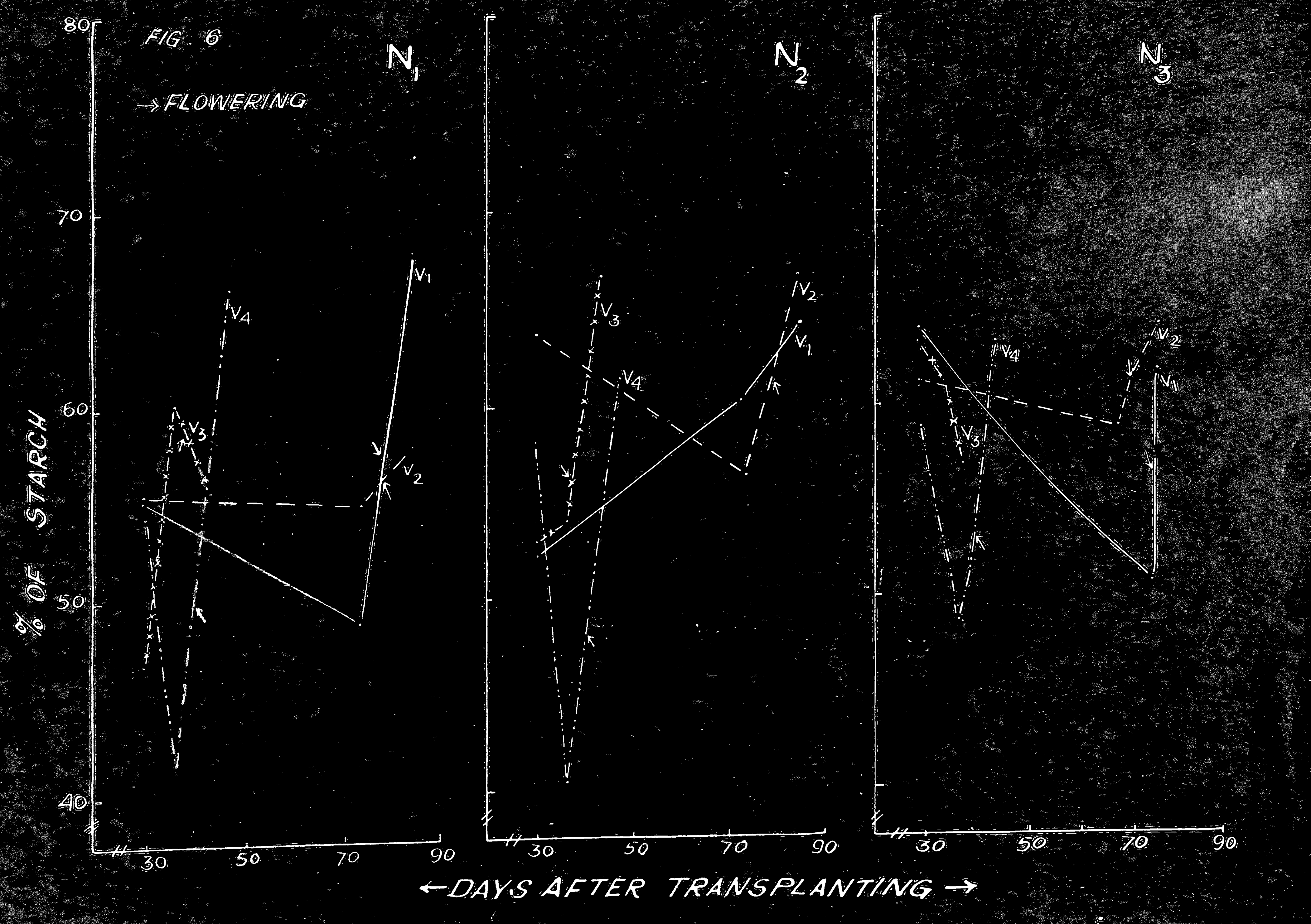
Table-12 b.
Total starch in leaf (%) at booting stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	48.81	60.50	50.64	53.32
IR. 8	55.04	55.21	58.83	56.36
PTB. 10	60.04	54.12	61.03	58.39
BBS. 2	41.73	40.38	48.70	43.60
Nitrogen mean	51.40	52.55	54.80	

Table-12 c.
Total starch in leaf (%) at early milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	67.90	64.37	61.73	64.67
IR. 8	57.98	66.65	64.04	62.89
PTB. 10	55.68	66.72	56.90	59.76
BBS. 2	66.09	61.34	63.02	63.48
Nitrogen mean	61.91	64.77	61.42	

STARCH CONTENT OF LEAF AT DIFFERENT GROWTH STAGES



The results also are presented in the form of graphs in figure 5 and 6. It is observed from Table 11-a-c that varietal difference in total carbohydrate content of leaves was significant at booting stage. Effect of nitrogen manuring was significant at vegetative stage and early milky stage. Interaction was not significant in any of the 3 growth stages studied. At booting stage BDS. 2 had significantly lower total carbohydrate in leaves than the other 3 varieties.

It is observed from the figure 5 that at N_1 level there was a decrease in total carbohydrate contents of the leaves of the two high yielding varieties from vegetative to booting stage. This is probably due to redistribution of leaf carbohydrates to other non-productive plant parts. From booting to early milky stage there was an increase in total carbohydrate content of the leaves of both the high yielding varieties. Booting to early milky stage is the period of intense carbohydrate metabolism. The photosynthetic activity of the leaves during this period is very high (Nagai 1959). A large part of the photosynthates produced during this period is stored in the leaves as well as other plant parts although considerable amounts of soluble sugars translocate to the developing panicles.

At N_2 and N_3 levels the two high yielding varieties behaved differently. In case of Jaya the total carbohydrate content increased from vegetative to booting stage and then decreased slightly from booting to early milky stage. At N_3 level, there was however, a decrease in total carbohydrate content of leaves of Jaya from vegetative to booting stage and then an increase to early milky stages. IR. 8 behaved similarly at N_1 and N_2 level but at N_3 level there was a continuous decrease from vegetative to early milky stage.

Carbohydrate biosynthesis in leaves are conditioned by two factors. (i) The capacity to produce (source) and the capacity to utilise (sink). From vegetative to booting stage carbohydrates are produced in the leaves by way of photosynthesis and are utilised by the growing tissues like stems and leaves for synthesis of new cell wall materials and for respiration. Thus the increase or decrease in carbohydrate content of the leaves is governed by the photosynthetic production of carbohydrates and their consumption by-way of synthesis of cell wall materials and by respiration. The increase in carbohydrate contents of the leaves of Jaya from vegetative to booting stage at N_2 level is probably due to increased photosynthetic activity of this variety from vegetative to booting stage coupled with a lower rate of translocation of the photosynthates to other tissues. The subsequent decline in leaf carbohydrate from booting to early milky stage is due to a greater rate of translocation of the photosynthates. Similarly the continuous decline in leaf carbohydrate from booting to early milky stage in IR. 8 at N_3 level was probably due to a greater rate of translocation of photosynthates to the developing panicles.

In case of tall varieties, PTB. 10 behaved differently from BBS. 2 at N_1 and N_3 levels. At N_1 level there was an increase in carbohydrate content of the leaves of PTB. 10 from vegetative to booting stage and then a sharp decline to early milky stage. This was exactly oposite of BBS. 2. This peculiar behaviour of PTB. 10 can be explained in a similar way with that of Jaya at N_2 level assuming a higher rate of photosynthetic production coupled with a lower rate of utilisation of photosynthates. At N_3 level there was a continuous decrease of leaf carbohydrate in PTB. 10 from vegetative to early milky stage. This is probably due to similar reason as explained for IR. 8.

STARCH :

The change in starch content of the leaves(Fig.6) of the four varieties at the 3 nitrogen levels were similar to that of total carbohydrates except that there was a slight increase in the starch content of Jaya and from booting to early milky stage at N_2 level and that of IR. 8 at N_3 level (instead of a decrease as observed in case of total carbohydrates). This indicates that these varieties had higher stored carbohydrates in the leaves at early milky stage similar to that observed for the other varieties.

TOTAL CARBOHYDRATES IN STEM :

Total carbohydrates in the stems of four varieties were determined only at 3 growth stages such as vegetative stage, booting stage and early milky stage. The results are presented in Table-13-a-d.

Table-13 a.
Total carbohydrate in stem (%) at vegetative stage
(30 days after transplanting)

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	69.75	73.81	53.93	65.83
IR. 8	58.00	62.75	68.09	62.95
PTB. 10	67.62	67.90	63.21	66.24
BBS. 2	63.78	69.31	67.34	66.81
Nitrogen mean	64.79	68.44	63.14	

	F-test	SE(m)	CD(0.05)
Variety	NS	2.446	—
Nitrogen	NS	2.136	—
Interaction	NS	4.271	—

Table-13 b.
Total carbohydrate in stem (%) at booting stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	72.40	67.06	73.49	70.98
IR. 8	78.21	65.28	82.31	75.27
PTB. 10	66.96	70.25	73.43	70.21
BBS. 2	76.71	73.15	73.15	74.34
Nitrogen mean	73.57	68.93	75.60	

	F-test	SE(m)	CD(0.05)
Variety	NS	2.541	—
Nitrogen	NS	2.201	—
Interaction	NS	4.401	—

Table-13
Total carbohydrate in stem (%) at early milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	69.87	70.06	71.05	70.56
IR. 8	69.50	73.06	69.90	70.82
PTB. 10	74.94	77.12	76.43	76.15
BBS. 2	69.50	69.97	68.18	69.22
Nitrogen mean	70.95	72.55	71.56	

	F-test	SE(m)	CD(0.05)
Variety	NS	2.286	—
Nitrogen	NS	1.98	—
Interaction	NS	3.961	—

It is observed from the above tables that the varietal difference in total carbohydrate content of the stems of the four varieties was not significant at any of the growth stages studied. Effect of nitrogen manuring as well as interaction were also not significant in any of the growth stages. The above observations are in contrast to Japanese workers, who observed that the low nitrogen responsive variety accumlated less carbohydrate in the stem (culm + leafsheath) under conditions of heavy manuring as compared to the high nitrogen responsive variety (Yamada, 1959, Baba, 1961, IRRI, 1967). Tanaka (1965) however, observed that the differences between high nitrogen responsive and low nitrogen responsive varieties became evident only in rainy season (kharif) and not in the dry season (rabi). Since the pot culture experiment was conducted during the rabi season the difference in the carbohydrate content in the stem of the varieties were not probably evident.

Effect of nitrogen manuring on carbohydrate content of the grain at various growth stages :

REDUCING SUGARS :

The reducing sugars contents of grain of four varieties at 3 nitrogen levels are given in table 14.

Table-14 a.
Reducing sugar in grain (%) at early milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	1.53	1.25	1.21	1.33
IR. 8	1.8[illegible]	1.37	1.12	1.46
PTB. 10	2.25	1.52	1.10	1.62
BBS. 2	1.46	1.26	1.66	1.46
Nitrogen mean	1.78	1.35	1.27	

	F-test	SE(m)	CD(0.05)
Variety	NS	0.072	—
Nitrogen	**	0.063	0.221
Interaction	**	0.126	0.388

Table-14 b.
Reducing sugar in grain (%) at mid milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	0.94	0.96	0.79	0.89
IR. 8	1.03	0.84	0.87	0.91
PTB. 10	1.36	1.42	1.60	1.46
BBS. 2	1.05	0.93	1.07	1.01
Nitrogen mean	1.09	1.03	1.08	

	F-test	SE(m)	CD(0.05)
Variety	**	0.040	0.123
Nitrogen	NS	0.034	—
Interaction	NS	0.060	—

Table-14 c.
Reducing sugar in grain (%) at maturity (Harvest).

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	0.27	0.18	0.16	0.20
IR. 8	0.34	0.18	0.21	0.24
PTB. 10	0.41	0.37	0.32	0.36
BBS. 2	0.38	0.33	0.15	0.28
Nitrogen mean	0.35	0.26	0.21	

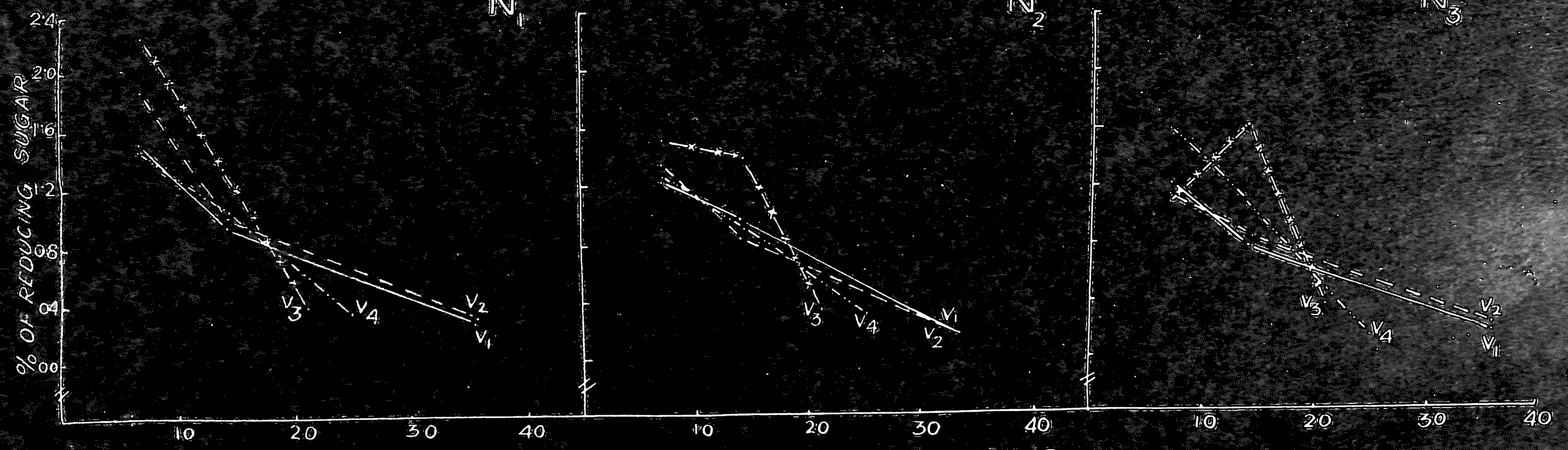
	F-test	SE(m)	CD(0.05)
Variety	**	0.014	0.043
Nitrogen	**	0.012	0.043
Interaction	**	0.024	0.073

It is observed from the Table-14 a-c that the varietal difference in reducing sugar content of grains was significant at mid milky stage and harvest. Both the high yielding varieties contained less reducing sugar in the grains than the tall varieties. Effect of nitrogen manuring on reducing sugar content of grain was significant at the early milky stage and at harvest. In both the stages nitrogen manuring was found to decrease reducing sugar content of the grains. Interaction was significant at early milky stage and at harvest.

As discussed earlier the major fraction of reducing sugar is glucose which can be utilised for the

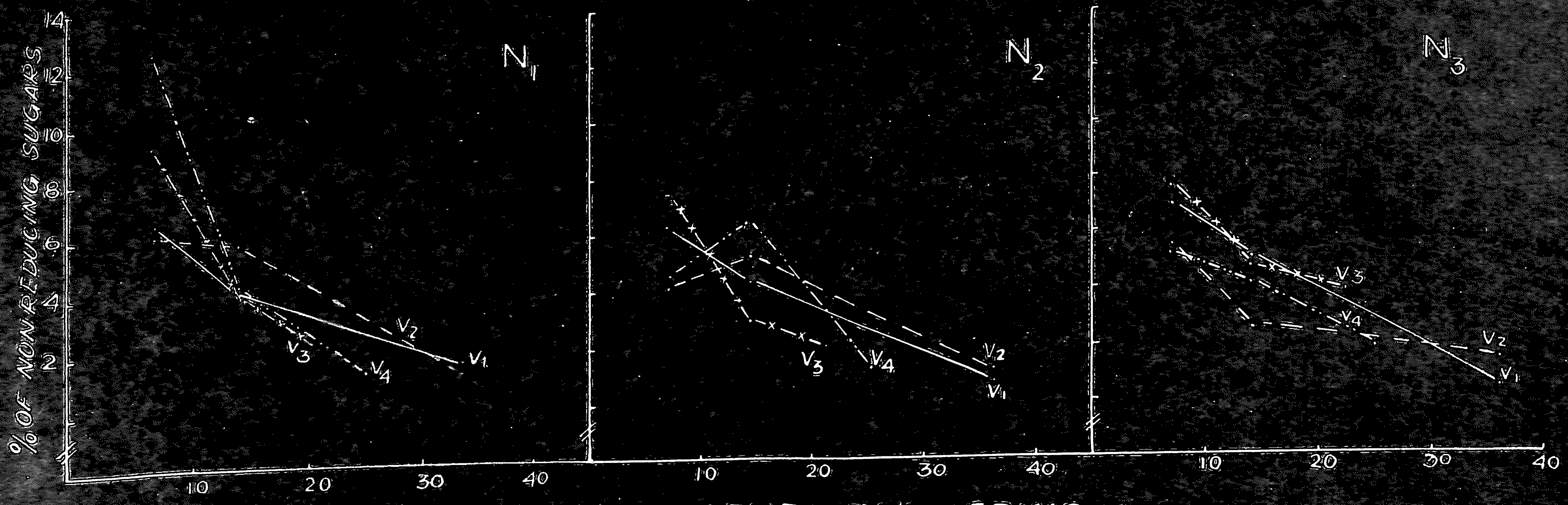
SOLUBLE SUGARS IN GRAIN AT DIFFERENT GROWTH STAGES

FIG. 7(a)



← DAYS AFTER FLOWERING →

FIG. 7(b)



← DAYS AFTER FLOWERING →

synthesis of starch by the ADPG pathway. A good part of it is also lost by way of respiration so that enough energy is liberated to drive the synthetic reactions. Synthetic reactions dominate during the grain filling stage. It has been observed by many workers (Nomura et al 1967) that with the increase in nitrogen manuring protein content and sometimes starch content of rice varieties increase. This indicated that nitrogen manuring accelerate the synthetic reactions and consequently respiratory loss of glucose. The decrease in reducing sugar content with the increase in nitrogen manuring at early milky stage and at harvest of all the varieties was partly due to respiratory loss of glucose and partly due to utilisation of glucose for starch synthesis. The lower reducing sugar content of the high yielding varieties as compared to tall varieties was probably due to both the above reasons as the high yielding varieties contained significantly more starch than the tall varieties at harvest.

The change in reducing sugar content of grains with the advance of grain filling has been ploted in figure 7(a). It is observed that from early milky stage up to harvest, there was a progressive decline in reducing sugar of the grains of all the varieties at different nitrogen levels except PTB. 10 at N_3 level. At mid milky stage PTB. 10 contained more reducing sugars in its grain at N_2 and N_3 level as compared to other varieties, BBS. 2 also contained more reducing sugar in its grain at N_3 level than the high yielding varieties. This is probably due to some slowing down effect of nitrogen manuring on synthetic reactions in tall varieties. In fact it can be observed from table-13-a,13-c that the total carbohydrate content of the tall varieties decreased with the increase in nitrogen manuring whereas for high yielding varieties there was a tendency to increase.

NON REDUCING SUGARS :

The non reducing sugars content of the grain of the four varieties are given in the Table 15a-c.

Table-15 a.
Non reducing sugars in grain (%) at early milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	6.66	6.36	7.09	6.70
IR. 8	6.26	4.29	5.49	5.38
PTB. 10	9.36	7.47	7.73	8.18
BBS. 2	12.60	4.63	5.22	7.48
Nitrogen mean	8.72	5.62	6.38	

	F-test	SE(m)	CD(0.05)
Variety	**	0.447	1.377
Nitrogen	**	0.387	1.192
Interaction	**	0.748	2.415

Table-15 b.
Non reducing sugar in grain (%) at mid milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	4.32	4.57	5.08	4.66
IR. 8	5.92	5.36	3.44	4.90
PTB. 10	4.19	3.01	4.89	4.03
BBS. 2	4.26	6.58	4.12	4.98
Nitrogen mean	4.67	4.88	4.38	

	F-test	SE(m)	CD(0.05)
Variety	**	0.382	0.989
Nitrogen	NS	0.321	—
Interaction	**	0.652	2.00

Table-15 c.
Non reducing sugar in grain (%) at maturity (Harvest).

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	1.62	0.80	1.39	1.27
IR. 8	1.50	1.11	1.46	1.35
PTB. 10	2.27	2.17	2.89	2.44
BBS. 2	1.40	1.31	0.95	1.22
Nitrogen mean	1.70	1.32	1.67	

	F-test	SE(m)	CD(0.05)
Variety	**	0.116	0.357
Nitrogen	**	0.100	0.308
Interaction	NS	0.201	—

It is observed from the above tables that the varietal difference in the non reducing sugar content of the grain is significant at all the stages of sampling. At the early milky stage the high yielding varieties contained less non reducing sugar in their grain as compared to the tall varieties. Differences were not so prominent at the subsequent growth stages. Effect of nitrogen manuring was significant at the early milky stage and at harvest. In general the non reducing sugar content of the grains decreased with the increase in nitrogen manuring. Interaction was significant in the early milky and the mid milky stages.

Decrease in non reducing sugar content of grain with the increase in nitrogen manuring was probably due to a greater utilisation of sucrose for starch synthesis at higher nitrogen levels. It is however difficult to conclude anything from the varietal difference in non reducing sugar content of the grains.

The change non reducing sugar content of the grains during the process of grain ripening is given in Fig.7(b). It is observed from this figure that there was a continuous decrease in non reducing sugar content of the grains from the early milky stage to harvest for all the varieties at N_1 and N_3 levels. At N_2 level, a slight increase in non reducing sugar content of the grains at mid milky stage was observed for IR. 8 and BBS. 2. This increase however was not statistically significant for IR. 8 but significant for BBS. 2. It is however difficult to explain the peculiar behaviour of BBS. 2 at N_2 level. BBS. 2 mainly is a kharif variety and at times behaves peculiarly in rabi season particularly if temperature is low.

TOTAL CARBOHYDRATE AND STARCH :

Total carbohydrate and starch content of the grains of the four varieties were determined only at 2 stages i.e. early milky stage and at harvest. The results are presented in the table-16 a-d.

Table-16 a.
Total carbohydrate in grain (%) at early milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	66.78	74.09	73.64	71.54
IR. 8	67.72	73.71	65.94	69.12
PTB. 10	72.78	79.44	68.09	73.44
BBS. 2	72.12	67.08	71.12	70.11
Nitrogen mean	69.85	73.58	69.70	

	F-test	SE(m)	CD(0.05)
Variety	NS	1.783	—
Nitrogen	NS	1.543	—
Interaction	NS	3.078	—

Table-16 b.
Total carbohydrate in grain(%) at Maturity(Harvest)

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	79.78	84.12	86.46	83.45
IR. 8	85.99	88.59	86.46	87.01
PTB. 10	82.99	72.12	69.50	74.87
BBS. 2	81.57	65.99	68.35	71.95
Nitrogen mean	82.58	77.69	77.69	

	F-test	SE(m)	CD(0.05)
Variety	**	0.848	2.61
Nitrogen	**	0.733	2.26
Interaction	**	1.469	4.53

Table-16 c.
Starch content in grain (%) at early milky stage.

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	58.58	66.97	65.33	63.63
IR. 8	59.62	68.04	59.30	62.32
PTB. 10	61.11	70.44	59.26	63.60
BBS. 2	58.05	61.11	64.29	61.15
Nitrogen mean	59.34	66.64	62.04	

Table-16 d.
Starch content in grain (%) at maturity (Harvest).

Nitrogen / Variety	N_1	N_2	N_3	Varietal mean
JAYA	77.88	83.13	84.90	81.97
IR. 8	84.18	87.29	86.13	85.86
PTB. 10	80.31	69.52	66.29	72.04
BBS. 2	79.79	64.29	67.26	70.45
Nitrogen mean	80.54	76.06	76.14	

	F-test	SE(m)	CD(0.05)
Variety	**	0.967	2.98
Nitrogen	**	0.84	2.58
Interaction	**	1.67	5.15

It is observed from the above tables that varietal difference, effect of nitrogen manuring as well as interaction were not significant for total carbohydrate in the grains at the early milky stage but were highly significant at harvest. The data for starch were identical to that of total carbohydrates at harvests.

It is observed from the Table-16 that the total carbohydrate and starch contains of the tall varieties decreased significantly with the increase in nitrogen manuring. In case of high yielding varieties there was an increase in carbohydrate content of the grains with the increase in nitrogen manuring. The starch content of the grains of Jaya at N_3 level was significantly higher than the starch content at N_1 level.

Karim, Choudhury and Islam (1967) observed a decrease in starch content of aman rice (low nitrogen responsive) when nitrogen manuring was increased from 40 - 120 lb per acre. It appears that increase in nitrogen manuring has a depressing effect on carbohydrate accumulation in the grains of low nitrogen responsive varieties. This might be due to a greater decrease in photosynthesis/ respiration ratio (P/R) of the low nitrogen responsive varieties with the increase in nitrogen manuring as compared to high nitrogen responsive variety (Baba 1961). The higher P/R ratio of the high nitrogen responsive varieties probably help them to maintain a higher levels of carbohydrate in their grains even under heavy application nitrogenous fertilisers.

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CHAPTER-V

SUMMARY

AND

CONCLUSION

SUMMARY AND CONCLUSION

A potculture experiment was conducted during the rabi season of 1970-71 with four rice varieties IR. 8, Jaya, PTB. 10 and BBS. 2 at 3 nitrogen levels (30,60, 120 kg/ha.). The different plants parts like, leaf blade, stem and grains were analysed for total carbohydrate, soluble carbohydrate, starch, reducing sugar and non reducing sugar at five growth stages. Besides the chemical analysis a number of growth characters such as leaf, stem and straw weights, leaf/stem ratio, thousand grain weight, thousand kernel weights and grain/kernel ratio were determined.

It was observed from the above study that the high yielding (Jaya, IR. 8) varieties had considerably larger weights of leaves at Harvest as compared to the tall varieties (PTB. 10, BBS. 2). The differences in the leaf weights of high yielding and tall varieties were not much at the vegetative stage irrespective of nitrogen manuring. This observation went against the observations of Japanese workers (Baba 1961, Tanaka 1964) who observed more leaves in low nitrogen responsive varieties at earlier growth stages under conditions of heavy nitrogen application. This was due to the fact that the tall varieties absorbed more nitrogen at the vegetative stage than the high yielding japonica varieties. Jaya and IR. 8 however have been found to absorb more nitrogen at the vegetative stage than the tall varieties (Nayak, 1970).

The stem and straw weight of the high yielding varieties were found to be frequently more than the tall varieties particularly at higher levels of nitrogen manuring. This was probably due to the larger number of tillers produced by the high yielding varieties at higher levels of nitrogen manuring.

The leaf/stem ratio which is an approximate measure of the relative proportions of photosynthetic organs to that of non-photosynthetic organs was found to be higher for high yielding varieties particularly in the post flowering stages. This was considered important as a larger photosynthetic apparatus in the post flowering stages would ensure adequate supply of photosynthates to the developing grains.

The thousand grain weights and thousand kernel weights of high yielding as well as tall varieties were found to increase significantly with the increase in nitrogen manuring. The grain/kernel ratio of the two high yielding varieties IR. 8 and Jaya and one of the tall varieties BBS. 2 did not change with the increase in nitrogen manuring. In case of PTB. 10 there was however a decrease in grain/kernel ratio with the increase in nitrogen manuring.

Varietal differences in reducing sugar content of the leaves were not found to be significant in the preflowering stages. In the post flowering stages particularly at mid milky stage and at harvest the high yielding varieties were found to contain significantly lower quantities of reducing sugars in their leaves than the tall varieties. The non reducing sugar and total soluble sugars in the leaves of the high yielding varieties also were found to be significantly lower than the tall varieties at mid milky stage and at harvest. The above observations could be explained by taking into consideration the higher grain/straw ratio of the high yielding varieties. Due to the higher grain/straw ratio a lower weight of vegetative tissues supply the nutrient requirement of a higher weight of the grains in the high yielding varieties. From the mid milky stage to maturity when the grain filling takes place the larger weights of the grains of high yielding varieties draw greater quantity of soluble sugars from the leaves and in this process deplete the leaves with respect to soluble sugars. This however does not take place in tall varieties where a higher weight of vegetative tissues supply the nutrient requirement of a lower weight of grains.

Total carbohydrate and starch content of the leaves were determined only at vegetative stage, booting stage and early milky stage. Since varietal differences were not significant in these stages any definite conclusion with regard to the differences between the high yielding and tall varieties were not drawn. Varietal difference in total carbohydrate contents of stem of the four varieties were also not significant at vegetative stage, booting stage and at early milky stage. Some Japanese workers (Yamada 1959, Baba 1961) observed a lower cabbohydrate content in the stem of the tall varieties as compared to high yielding varieties at higher nitrogen levels. However, according to Tanaka (1965) these differences could not be observed during rabi season probably due to low temperature.

The grains of the four rice varieties were analysed at early milky stage, mid milky stage and at harvest. Significant differences in the carbohydrate content of the grains of the high yielding and tall varieties were observed at harvest. The high yielding varieties were found to contain significantly lower amounts of reducing sugars but higher amounts of total carbohydrates and starch in their grains than the tall varieties at harvest. With the increase in nitrogen manuring the reducing sugar content of the grains of the high yielding varieties decreased at harvest. There was however an increase in the total carbohydrate and starch content of the grains of the high yielding varieties with the increase in nitrogen manuring. The effect of nitrogen manuring on the reducing sugar, total carbohydrate and starch content of the grains of the tall varieties was exactly opposite to that of the high yielding varieties. At higher levels of nitrogen manuring there was an increase in reducing sugar content and a significant decrease in the total carbohydrate and starch content of the grains of the tall varieties.

The above observations could be explained by taking into consideration the favourable leaf/stem ratio and P/R (Photosynthesis/Respiration) ratio of the high yielding varieties at higher nitrogen leaves. A larger photosynthetic apparatus coupled with a higher rate of photosynthesis at higher nitrogen levels supplied adequate quantities of photosynthates to the grains of the high yielding varieties to increase the total carbohydrate and starch content of the grains. In case of tall varieties the photosynthates produced by a lower weight of leaves were wasted to supply the respiratory demands of a larger weight of nonphotosynthetic organs (stems) and could not translocate in sufficient quantities to the grains, resulting in lower carbohydrate content of the grains.

To sum up

i. a higher leaf/ stem ratio in the post flowering growth stages,

ii. a significantly lower amount of reducing sugar, non reducing sugar and total soluble sugars in the leaves at harvest,

iii. an increase in total carbohydrate and starch content of the grains with the increase in nitrogen manuring

might be used as some of the important morphological and biochemical parameters to judge the high nitrogen responsiveness of a variety.

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APPENDIX

T A B L E - 1.

WEIGHT OF LEAF (g/pot) AT DIFFERENT STAGES OF GROWTH.
(on oven dry basis).

Treatments	Vegetative stage		Booting stage		Early milky stage		Midmilk stage		Maturity (harvest)	
	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
V_1N_1	1.80	2.10	4.00	3.50	2.55	2.93	3.22	3.43	5.36	3.84
V_1N_2	2.50	3.10	5.20	4.40	3.62	3.19	4.07	4.31	6.10	6.87
V_1N_3	3.20	4.60	6.20	5.50	6.76	5.89	5.70	6.14	7.80	9.29
V_2N_1	1.80	1.90	3.00	2.80	2.93	3.64	4.20	3.40	4.26	4.95
V_2N_2	2.60	2.90	4.40	5.40	6.62	4.73	7.90	4.62	6.36	6.48
V_2N_3	3.40	4.20	7.00	6.00	7.35	6.45	1.40	7.13	12.78	10.75
V_3N_1	2.30	2.60	1.80	1.70	1.54	1.76	2.42	1.51	2.00	2.01
V_3N_2	3.20	2.90	2.70	2.40	2.66	2.51	3.69	2.29	2.58	3.40
V_3N_3	3.20	3.50	4.40	3.00	4.04	4.55	5.06	3.60	4.00	4.87
V_4N_1	2.50	2.20	2.20	1.60	2.05	3.29	5.06	3.09	2.90	2.75
V_4N_2	3.00	3.30	3.20	3.00	3.81	3.98	5.63	5.32	3.91	3.84
V_4N_3	4.30	4.10	6.40	5.06	4.04	4.98	7.45	7.24	4.82	6.70

TABLE - 2.

WEIGHT OF STEM (g/pot) AT DIFFERENT STAGES OF GROWTH
(on oven dry basis).

Treatments	Vegetative stage		Booting stage		Early milky stage		Midmilk stage		Maturity(harvest)	
	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
V_1N_1	1.60	2.39	9.49	4.07	6.69	6.36	6.34	5.25	6.51	4.40
V_1N_2	2.06	3.48	10.50	9.10	7.47	5.13	8.56	9.47	7.30	5.14
V_1N_3	2.75	4.69	12.80	9.40	13.62	13.93	11.69	11.26	11.52	11.60
V_2N_1	1.40	1.45	6.57	4.83	6.35	7.15	8.63	6.29	5.59	5.06
V_2N_2	1.59	2.33	8.63	8.90	13.20	7.12	10.62	7.38	9.99	8.84
V_2N_3	4.02	3.43	14.28	11.24	16.30	10.84	15.64	13.13	10.43	11.18
V_3N_1	2.63	2.85	3.16	3.99	4.05	4.69	3.75	4.03	6.37	4.23
V_3N_2	4.23	4.31	6.30	5.31	7.17	7.25	8.63	6.96	7.70	7.43
V_3N_3	5.58	3.64	11.09	6.69	13.54	11.71	11.78	9.84	8.27	9.62
V_4N_1	2.37	1.87	4.36	3.65	4.71	6.38	11.28	7.02	6.64	5.65
V_4N_2	3.00	3.91	6.66	4.16	7.80	7.07	11.71	11.60	9.06	4.42
V_4N_3	5.22	4.40	9.02	5.21	11.27	10.50	13.04	11.85	8.74	7.24

TABLE - 3.

WEIGHT OF STRAW (g/pot) AT DIFFERENT STAGES OF GROWTH.
(on oven dry basis).

Treatments	Vegetative stage		Booting stage		Early milky stage		Midmilk stage		Maturity(harvesting	
	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
V_1N_1	3.40	4.49	13.49	7.57	9.24	9.29	9.56	8.68	11.87	8.24
V_1N_2	4.56	6.58	15.70	13.50	11.09	8.32	12.63	13.78	11.40	12.01
V_1N_3	5.95	9.29	19.00	14.90	20.38	19.78	17.39	17.40	19.32	20.89
V_2N_1	3.20	3.35	9.57	7.63	9.28	10.79	12.83	9.69	9.85	10.01
V_2N_2	4.19	5.23	13.03	14.30	19.82	11.85	16.54	12.00	16.35	15.32
V_2N_3	7.42	7.63	21.28	17.24	23.65	17.29	23.54	20.26	23.81	11.93
V_3N_1	4.93	5.45	4.96	5.69	5.59	6.45	5.15	5.54	8.37	6.24
V_3N_2	7.43	7.21	9.00	7.71	9.83	9.76	11.05	9.25	10.28	10.83
V_3N_3	9.78	7.14	15.42	9.69	17.58	16.26	15.47	13.44	12.27	14.49
V_4N_1	5.37	4.27	6.56	5.25	6.76	9.67	16.34	10.11	9.54	8.40
V_4N_2	6.00	7.21	9.86	7.16	11.61	11.05	17.34	16.92	12.97	8.26
V_4N_3	9.52	8.50	15.42	10.27	15.31	15.48	20.49	19.07	13.56	13.94

Treatments	TABLE - 4. 1000 grain weight in gm.		TABLE - 5. 1000 Kernel weight in gm.		TABLE - 6. Grain/Kernel weight	
	R_1	R_2	R_1	R_2	R_1	R_2
V_1N_1	25.65	24.82	22.49	21.32	1.14	1.17
V_1N_2	25.80	26.03	23.02	23.24	1.12	1.12
V_1N_3	26.43	26.56	24.43	22.41	1.18	1.18
V_2N_1	24.50	25.01	22.46	21.40	1.09	1.17
V_2N_2	25.84	24.15	21.81	22.35	1.18	1.08
V_2N_3	26.05	26.62	23.21	23.34	1.12	1.14
V_3N_1	17.54	18.54	14.46	13.99	1.21	1.33
V_3N_2	14.68	20.56	16.00	16.85	1.23	1.22
V_3N_3	20.06	20.42	18.40	18.00	1.09	1.13
V_4N_1	24.43	24.34	20.01	20.02	1.22	1.21
V_4N_2	25.36	26.26	21.15	21.86	1.20	1.20
V_4N_3	26.02	26.58	22.34	21.64	1.16	1.23

TABLE - 7.

REDUCING SUGAR (% of dry weight) IN LEAF AT DIFFERENT STAGES OF GROWTH.

Treatments	Vegetative stage		Booting stage		Early milky stage		Midmilk stage		Maturity(harvest)	
	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
V_1N_1	0.75	0.73	1.09	1.06	0.54	0.73	0.38	0.34	0.16	0.23
V_1N_2	0.80	1.47	1.46	1.09	0.53	0.51	0.75	0.70	0.25	0.21
V_1N_3	1.46	2.25	1.88	1.27	0.59	0.54	0.78	0.76	0.18	0.23
V_2N_1	0.72	0.77	0.89	1.03	0.41	1.45	0.37	0.50	0.22	0.18
V_2N_2	1.02	1.05	1.48	1.17	0.43	1.11	0.51	0.77	0.23	0.37
V_2N_3	1.53	1.75	1.79	1.69	0.48	0.41	0.53	0.59	0.17	0.15
V_3N_1	0.69	0.56	1.15	1.00	0.75	0.87	0.96	1.05	0.43	0.33
V_3N_2	0.97	0.90	1.25	1.29	0.83	0.93	0.65	0.82	0.42	0.43
V_3N_3	1.12	1.14	1.62	1.81	1.06	1.11	1.75	0.75	0.46	0.29
V_4N_1	0.98	0.62	1.01	1.01	0.53	0.52	0.60	0.82	0.24	0.40
V_4N_2	1.16	1.14	1.49	1.17	0.75	0.64	0.77	0.66	0.43	0.43
V_4N_3	1.40	2.25	2.19	1.55	0.83	0.88	1.00	0.94	0.26	0.31

TABLE - 8

Reducing Sugar (% of Dry Weight) in Grain at different Stages of growth.

Treatments	Early milky stage		Midmilk stage		Maturity (harvest)	
	R_1	R_2	R_1	R_2	R_1	R_2
V_1N_1	1.24	1.82	0.83	1.06	0.24	0.31
V_1N_2	1.00	1.50	0.92	1.01	0.19	0.18
$V1N_3$	1.06	1.37	0.77	0.82	0.17	0.16
V_2N_1	1.29	2.38	0.96	1.11	0.36	0.33
V_2N_2	0.82	1.93	0.85	0.84	0.21	0.17
V_2N_3	0.88	1.36	0.81	0.93	0.20	0.22
V_3N_1	1.89	2.61	1.40	1.33	0.44	0.38
V_3N_2	1.44	1.61	1.36	1.49	0.43	0.31
V_3N_3	1.02	1.18	1.64	1.57	0.34	0.30
V_4N_1	1.27	1.66	0.94	1.16	0.41	0.36
V_4N_2	1.04	1.49	0.81	1.06	0.34	0.33
V_4N_3	2.07	1.26	1.06	1.08	0.15	0.16

TABLE - 9.

NON REDUCING SUGAR (% of dry weight) IN LEAF AT DIFFERENT STAGES OF GROWTH.

Treatments	Vegetative stage		Booting stage		Early milky stage		Midmilk stage		Maturity(harvest)	
	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
V_1N_1	15.04	11.15	19.85	6.06	8.40	6.09	6.06	5.23	0.66	1.14
V_1N_2	18.78	12.88	15.79	7.91	6.91	8.48	6.25	4.70	1.09	0.67
V_1N_3	16.93	7.66	15.96	8.77	5.44	6.52	5.89	4.23	1.89	1.13
V_2N_1	16.57	12.24	13.63	9.89	7.40	9.40	7.43	5.55	1.34	1.36
V_2N_2	17.09	17.08	12.76	8.06	7.92	8.41	4.80	4.70	2.84	1.14
V_2N_3	15.08	15.03	15.56	8.11	5.75	6.68	5.67	5.01	0.84	0.89
V_3N_1	14.92	12.41	12.76	10.00	10.47	9.55	11.86	11.27	3.08	3.96
V_3N_2	16.77	18.06	13.98	15.00	8.43	10.19	11.67	12.12	4.23	3.04
V_3N_3	18.43	23.50	11.95	11.54	8.83	8.75	12.52	12.49	3.21	2.86
V_4N_1	14.55	14.45	13.66	23.39	8.81	7.07	7.57	7.86	3.35	4.60
V_4N_2	14.05	11.72	21.30	16.20	8.13	8.85	8.88	7.48	3.21	5.03
V_4N_3	14.98	7.21	14.61	14.62	6.64	5.16	9.01	9.63	2.31	3.58

TABLE - 10

Nonreducing Sugar (% of dry Weight) in grain at different stages of growth.

Treatments	Early milky stage		Midmilk stage		Maturity (Harvest)	
	R_1	R_2	R_1	R_2	R_1	R_2
V_1N_1	6.46	6.87	4.68	3.96	1.51	1.74
V_1N_2	5.59	7.14	4.36	4.78	0.64	0.97
V_1N_3	6.30	7.89	4.32	5.85	1.74	1.65
V_2N_1	7.64	4.89	8.72	9.12	1.01	1.93
V_2N_2	4.18	4.40	5.91	4.81	1.15	1.07
V_2N_3	4.04	6.54	3.39	3.49	1.25	1.68
V_3N_1	8.17	10.56	4.26	4.13	2.53	2.03
V_3N_2	6.38	8.60	2.66	3.37	2.37	1.98
V_3N_3	6.80	8.66	5.03	4.76	2.77	3.01
V_4N_1	11.80	13.41	3.92	4.61	1.40	1.40
V_4N_2	4.73	4.54	4.65	8.51	1.48	1.44
V_4N_3	4.84	5.61	3.80	4.44	0.87	1.03

TABLE - 11.

TOTAL SOLUBLE SUGARS (% of dry weight) IN LEAF AT DIFFERENT STAGES OF GROWTH.

Treatments	Vegetative stage		Booting stage		Early milky stage		Midmilk stage		Maturity (harvest	
	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2	R_1	R_2
V_1N_1	15.79	11.88	20.94	7.12	8.94	6.82	6.44	5.57	0.72	1.67
V_1N_2	19.58	14.35	17.25	9.00	7.44	8.99	7.00	5.40	1.34	0.88
V_1N_3	18.39	9.91	17.85	10.04	6.03	7.06	6.67	4.99	2.03	1.36
V_2N_1	17.29	13.01	14.62	10.92	7.81	10.85	7.80	6.05	1.56	1.54
V_2N_2	18.11	10.13	14.24	9.26	8.35	9.52	5.31	5.47	3.07	1.51
V_2N_3	16.61	16.78	17.35	9.80	6.23	7.09	6.20	5.60	1.01	1.04
V_3N_1	15.61	12.97	13.91	11.00	11.22	10.42	12.82	12.33	3.55	4.29
V_3N_2	17.74	18.96	15.23	16.29	9.26	11.12	12.32	12.94	4.65	3.47
V_3N_3	9.55	14.64	16.57	13.35	9.89	9.86	13.27	13.24	3.67	3.15
V_4N_1	15.53	15.07	14.67	24.40	9.34	7.59	8.17	8.68	3.59	5.00
V_4N_2	15.21	12.86	16.85	17.37	8.88	9.50	9.65	8.14	3.64	5.51
V_4N_3	16.61	9.46	16.80	16.17	7.47	6.04	10.04	10.75	2.57	3.89

T A B L E - 12

Totalsoluble Sugar (% of dry weight) in grain at different stages of growth.

Treatments	Early milky stage		Midmilky stage		Maturity(Harvest)	
	R_1	R_2	R_1	R_2	R_1	R_2
V_1N_1	7.70	8.69	5.51	5.02	1.75	2.05
V_1N_2	6.59	8.64	5.28	5.79	0.83	1.15
V_1N_3	7.36	9.26	5.09	6.67	1.31	1.81
V_2N_1	8.93	7.27	9.68	10.23	1.73	2.26
V_2N_2	5.00	6.33	6.76	5.65	1.36	1.24
V_2N_3	5.32	7.90	4.20	4.42	1.45	1.90
V_3N_1	10.06	13.17	5.46	5.46	2.96	2.41
V_3N_2	7.78	10.21	4.02	4.86	2.90	2.29
V_3N_3	7.82	9.84	6.67	6.33	3.11	3.31
V_4N_1	13.05	15.07	4.86	5.77	1.81	1.76
V_4N_2	5.77	6.03	5.46	9.57	1.82	1.47
V_4N_3	6.91	6.87	4.86	5.52	1.02	1.19

TABLE - 13

Total Carbohydrate (% of dry weight) in leaf at different stages of growth.

Treatments	Vegetative stage		Booting stage		Early milky stage	
R	R_1	R_2	R_1	R_2	R_1	R_2
V_1N_1	67.87	69.87	65.56	60.12	79.06	72.50
V_1N_2	64.94	69.00	71.00	76.25	71.56	73.62
V_1N_3	81.50	75.12	66.50	62.68	73.81	62.75
V_2N_1	68.94	72.31	63.87	71.75	73.62	71.00
V_2N_2	[illegible]	78.50	64.06	69.87	79.43	71.75
V_2N_3	78.12	72.44	67.45	77.37	71.56	69.87
V_3N_1	61.37	60.87	66.69	78.31	66.50	66.50
V_3N_2	67.62	75.31	69.31	70.44	77.75	76.06
V_3N_3	83.19	77.75	81.17	70.81	63.50	70.06
V_4N_1	63.12	75.87	60.17	62.37	71.37	77.75
V_4N_2	65.75	78.69	58.62	56.37	72.12	68.94
V_4N_3	73.81	69.91	50.81	68.56	70.10	69.50

TABLE - 14

Total Carbohydrate (% of dry weight) in stem at different stages of growth.

Treatments	Vegetative stage		Booting stage		Early milky stage	
	R_1	R_2	R_1	R_2	R_1	R_2
V_1N_1	77.50	62.00	69.31	75.50	67.25	72.50
V_1N_2	72.12	75.50	58.06	76.06	68.56	71.56
V_1N_3	52.06	55.81	80.37	66.62	80.75	62.75
V_2N_1	55.06	60.94	74.56	81.87	68.00	71.00
V_2N_2	64.81	60.69	66.50	64.06	74.19	71.94
V_2N_3	57.50	78.69	80.75	84.87	65.75	70.06
V_3N_1	66.69	68.56	67.62	66.31	71.94	77.94
V_3N_2	66.50	69.31	71.19	69.31	78.75	75.50
V_3N_3	58.81	67.62	72.50	74.37	78.31	74.56
V_4N_1	62.75	64.81	74.81	73.62	71.94	67.06
V_4N_2	68.75	69.87	70.62	75.69	61.44	78.50
V_4N_3	69.31	65.37	75.87	70.44	67.62	68.75

TABLE - 15

Total Carbohydrate (% of dry weight) in grain at different stages of growth.

Treatments	Early milky stage		Harvesting	
	R_1	R_2	R_1	R_2
V_1N_1	64.25	69.31	80.94	78.62
V_1N_2	75.31	73.87	88.44	79.81
V_1N_3	76.66	70.62	84.31	88.62
V_2N_1	71.00	64.44	83.93	88.06
V_2N_2	72.10	75.31	89.56	87.62
V_2N_3	63.69	68.19	87.50	88.44
V_3N_1	72.69	72.87	84.87	81.12
V_3N_2	82.44	76.44	7287	7137
V_3N_3	68.19	68.00	69.13	69.87
V_4N_1	93.25	71.00	82.84	80.25
V_4N_2	72.69	61.47	66.01	65.87
V_4N_3	65.00	77.37	67.70	69.01

TABLE - 16

Starch content (% of dry weight) in leaf at different stages of growth.

Treatments	Vegetative stage		Booting stage		Early milky stage	
	R_1	R_2	R_1	R_2	R_1	R_2
V_1N_1	52.08	57.99	44.62	53.00	70.12	65.68
V_1N_2	55.36	50.35	53.75	67.25	64.12	64.63
V_1N_3	63.11	65.21	48.65	52.64	67.78	55.69
V_2N_1	51.65	59.30	49.25	60.83	55.81	60.15
V_2N_2	66.95	60.37	49.82	60.61	71.08	62.33
V_2N_3	61.51	55.66	50.10	67.57	65.30	62.78
V_3N_1	45.76	47.90	52.78	67.31	55.28	56.08
V_3N_2	49.88	56.35	54.08	54.15	68.49	64.94
V_3N_3	63.64	63.11	64.60	57.46	53.61	60.20
V_4N_1	47.99	60.80	45.50	37.97	62.03	70.16
V_4N_2	50.54	65.83	41.47	39.00	63.24	49.44
V_4N_3	57.20	60.48	44.01	52.39	62.63	63.46

TABLE - 17

Starch content (% of dry weight) in grain at different stages of growth.

Treatments	Early milky stage R_1	Early milky stage R_2	Harvest (Maturity) R_1	Harvest (Maturity) R_2
V_1N_1	56.55	60.62	79.19	76.57
V_1N_2	68.72	75.23	87.61	78.66
V_1N_3	69.30	61.36	83.00	86.81
V_2N_1	62.07	57.17	82.56	85.80
V_2N_2	67.01	68.98	88.20	86.38
V_2N_3	58.37	60.24	86.05	86.22
V_3N_1	62.63	59.70	81.91	78.71
V_3N_2	74.66	66.23	69.97	69.08
V_3N_3	60.37	58.16	66.02	66.56
V_4N_1	60.18	55.93	81.08	78.50
V_4N_2	66.92	55.41	64.19	64.40
	58.09	70.50	66.70	67.82