REVIEW OF LITERATURE

Tillering in rice depends on genetical, environmental and edaphic factors. Genetic factors constitute the inherent tillering potential among varieties. The environmental factors comprise, mainly, temperature, light and photoperiod. The edaphic factors involve nutrition, water regime and stress conditions like salinity, drought and water logging. Besides, these factors, the internal auxin concentration in the plant and the external application of growth regulators also influence tillering. However, a brief review of only those aspects pertaining to the study under report is give below.

1. <u>Nutrition in relation to tillering</u>.

Whyte (1960) quoted the observations of Watson (1956) that, in cereals like wheat and barley, nitrogen increased both number of tillers and leaf area per tiller but did not greatly influence the number of leaves per shoot. Phosphorus increased the tiller number as well as leaf area in early stages of growth, but hastened senescence of leaves and eventually reduced leaf area. Potassium had little effect on tiller number but consistently increased leaf area and delayed senescence of leaves. A survey of literature on nutrition affecting tillering and yield in rice indicated that there was a positive correlation between the number of tillers and nitrogen content during tillering stage (Kumura 1956) . Sekiya (1963) reported the effect of nitrogen and phosphorus deficiency on development of tiller bud. Deficiency of N and P reduced tillering

while deficiency of P caused less repression of tiller bud growth. The critical contents of each element required for increase in tillers were reported as follows: Nitrogen content was about 2.5 per cent (Ishizuka and Tanaka, 1963) phosphorus content about 0.25 per cent P_2O_5 (Honya, 1958) and potassium 1.5 per cent (Kiuchi and Ishizaka, 1961).

In water culture experiment Ishizuka and Tanaka (1960) studied the effect of elements on the characteristics of various yield components. The decrease in yield caused by nitrogen, phosphorus and sulphur deficiencies was associated with a decrease in number of panicles and grain number per panicle. Potassium and magnesium deficiencies decreased yields by lowering the seed setting rate and weight of 1000 grains, calcium deficiency caused a decrease in seed setting rate. Okuda and Takahashi (1964) noted that silicon deficiency at vegetative stage decreased the number of panicles, and in the reproductive stage decreased the number of spikelets per panicle and the percentage of ripened grains. The length of the panicle was shortened by silicon deficiency in the reproductive growth stage.

Tillering, according to Kiuchi et al. (1962) was influenced more by absorption rate rather than nitrogen content per se in the plant, had direct proportion to nitrogen content of more than 1 per cent in early stages and was decided more by the soluble nitrogen than other nitrogen fractions. They further suggested that for rapid tillering, nitrogen uptake in excess of 1 mg per

day per gram dry weight was optimum. Tillering was
independent of rate of K uptake but ceased at a plant K
content of less than 1 per cent. Deficiency of magnesium
tended to increase tillering. Takahashi et al. (1956)
stated that tillering was directly related to translocation
of nitrogen from leaf blade and sheath to stem. Where N
concentration in stem was low at tillering, as in P deficient
plants, few tillers were formed. In K deficient plants, the
nitrogen content of the stem was high at tillering and
continued to increase until flowering. The number of tillers
produced was high. In all cases, soluble carbohydrate
content of stem rose during tiller development and its
function was primarily one of tiller nutrition. Oshima(1962)
in his studies on nitrogen nutrition on tillering of rice
plant, stated that maximum content of amino acids in stem
occurred during tillering.

Tanaka and Garcia (1965) observed that during
tillering stage, an increase in N content of culm above 2
per cent led to an increase in number of tillers 5 and 10
days later. The carbohydrates required by a developing
tiller appeared to be provided by the internode immediately
above its node of origin. Tanaka et al. (1965) studied
tillering and leafing patterns of varieties with different
tillering capacities under low and high nitrogen levels and
suggested that varietal differences in tillering may be the
result of varietal differences in nitrogen absorbing
capacities. Active tillering variety showed a shorter leaf-
ing interval and produced leaves faster than a weak tillering
variety. Lei and Xi (1962) studied tillering rate of rice

plants at different densities. The mean initial rate of tiller formation per seedling was positively and linearly correlated with level of nitrogen. The lower the plant density the greater was the effect of nitrogen. The death of late tillers under field conditions was caused by unfavourable plant environment rather than intrinsic weakness of late tillers.

Recent studies at International Rice Research Institute, IRRI, (1968) indicated that varietal difference was a consequence of difference in nitrogen content, and probably of auxin level as well, and tillering stopped when the leaf nitrogen was less than 2 per cent. The rate of tillering was found to be inversely proportional to the total number of tillers present at a particular period. Yoshida and Hayakawa (1971) reported that 5 per cent nitrogen 0.2 per cent phosphorus, and 1.5 per cent potassium in the leaf blades were required for maximum tillering rate. If the nutrient content of the leaf blade decreased to 2 per cent nitrogen, 0.03 per cent phosphorus and 0.5 per cent potassium, the tillering rate became zero. The total number of tillers retarded subsequent tiller production to varying degrees in different varieties. More tillers were produced at the same nitrogen content by high tillering variety than by low tillering type. High carbohydrate content, especially soluble carbohydrate, was a characteristic feature of high tillering types which could lead to enhanced protein formation (Matsubayashi 1968).

Ishizuka (1932), from studies on a short term variety of Hokkaido, demonstrated that nitrogen was required

for the first 9 weeks (at least 7 weeks) from the seventh day after germination. Thereafter, nitrogen starvation did not effect the yield. Osugi et al (1938),using a mid term variety in Kyoto, found that during the first 6 weeks, a one week nitrogen starvation obviously decreased grain yield. Nitrogen starvation at later stages did not affect yield if nitrogen had been supplied for 9 to 13 weeks at the early growth stages. Kasugai (1939) using a mid term variety in Tokyo found that nitrogen starvation hardly decreased yield in growth period, 2 months following transplanting and that earlier nitrogen starvation caused a drastic reduction in grain yield.

2. Tillering as affected by light intensity

Kakizaki (1965) reported that tillering in Norin 1 (panicle number type) was affected chiefly by light intensity, and the effects varied according to temperature while in Zosan No.1 (panicle weight type) tillering was affected predominantly by light intensity and temperature had little influence on tillering. Shimizu et al. (1962), reported that tillering in Mihonishiki rice, grown in water culture, was reduced as shading of (natural) light was increased. The lower limit of light for tillering was approximately 200 $cal/cm^2/day$, corresponding to approximately 60 per cent shading. Yamagata (1958) reported that under strong light intensity (horizontal incidence about 200 per cent normal) the number of tillers, ears and grains per hill increased in several rice varieties whether grown early or at normal time. Under weak intensity of light and under various

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combinations of strong, weak and normal light intensity, the number of tillers, ears and grains per hill increased with intensity and quantity of light. Auda et al. (1966) [Hamid] observed that high tillering in orchard grass appeared to be associated with factors that have potentially high photosynthesis and carbohydrate storage. They observed that nitrogen stimulated tillering and tillering was low at 10 - 15°C. Tillering increased with increase in light intensity from 25 per cent to normal sun light.

3. Tillering and growth under upland dry-sown and transplanted conditions

Bhan and Pande (1966) reported, that in a short term variety Dular, most of the tillers were produced in 37 days after sowing. Tillers that emerged later had lower percentage of fertility and bore, on an average, a less number and weight of sound grains. Saini and Ram (1966) observed that maximum tillering was recorded at 9 weeks after transplanting. Tillering rate was the highest during 7 weeks after transplanting in early varieties. Tiller mortality was lowest in early maturing varieties. Enyi (1964) reported that tillering was the same under dry and wet water regimes, but tiller mortality was more in the former, particularly at low level of phosphorus. Increase in P level enhanced tiller number and leaf number. Sanchez and Bradfield (1970) observed that tillering and dry matter were more in granulated soil system (dry-sown) than in puddled conditions upto tillering stage. Plant nitrogen content was considerably higher in the puddled plots.

During the 6th week, the granulated treatments began to
show N deficiency symptoms, while puddled plants maintained
their dark green colour. The puddled treatments showed more
dry matter and higher nitrogen uptake at the panicle
initiation stage. The granulated treatments responded
rapidly to N top dressing. Grain yield response to top
dressing at the panicle initiation stage was substantial in
granulated treatments. The puddled treatment outyielded
the granulated by about 1.5 tonnes/ha. Yield differences
were associated with number of grains per panicle and not
with the other yield components.

The panicle length, number of filled grains and
weight of the filled grains increased with the height of the
tiller (IRRI, 1970) while the per cent of unfilled grains
decreased. The positive correlation between the grain
number per panicle of main shoot and the leaf nitrogen per
cent was reported by Kumura (1956, 1957). Wada (1969),
Murayama (1967) and Shimizu (1967) also reported that
the number of spikelets or grains per unit area was positively
correlated with the amount of nitrogen absorbed by the end
of spikelet initiation stage or flowering.

4. Factors affecting the panicle weight in rice

Recently Yoshida (1972) presented a review on
the physiological aspects of grain yield with particular
reference to rice. Murata (1969) observed that the yield
capacity in rice was a product of number of grains per m^2 of
land and the potential size of the grains. Yoshida (1972)
reported that the possible contribution of photo-synthesis of

different plant parts to the grain were based on (a) potential photo-synthetic activity (b) longevity of the photo-synthetic tissue during the ripening period and (c) light environment in a canopy. In rice, the flag leaf contributed about 60 per cent of the carbohydrates, while the flag leaf together with second leaf contributed about 90 per cent. The efficiency of the top two individual leaves was the same with the second leaf having an edge over the flag leaf (IRRI, 1972). The efficiency of lower leaves (below second leaf) was lower than the top leaves (Matsubayashi,1968). Compared with the leaf blades, the net photosynthesis of the ear and leaf sheaths was very low (Yoshida, 1972). If a part of the green tissue was shaded or removed, the photosynthetic rate of the remaining green tissue increased in rice (Lizandr and Brovtsyna,1964) and in wheat (King et al. 1967; Lupton 1966).

Among grain crops, corn and sorghum had higher photosynthetic rate than rice, wheat, soybean and peas (Yoshida, 1972). Varietal differences in photosynthetic rate of leaves existed in rice (Chandler, 1969; Murata, 1957; Osada, 1971 and Murty et al. 1970, 1972). The photo-synthetic activity was proportional to difference in nitrogen content in leaf (Fujiwara, 1964). Photosynthetic activity was obviously controlled by chlorophyll content. Their experiments also revealed that soluble protein in the chloroplast was also important. Increase in photosynthetic rate at higher leaf nitrogen was demonstrated by Takano and Tsunoda (1970) Tanaka and Matsushima (1971). Matsushima (1967), Tanaka et al. (1966) reported that photosynthetic

rate increased with chlorophyll content. The rate of

photosynthesis also depended on the demand by the sink

(Evans, 1970). The varietal differences in the leaf

photosynthetic rate might be caused by variety-environment

interaction since the temperature and light regimes affected

the morphological characters of leaf (Friend, 1966).

Translocation of carbohydrates amongst the

tillers was apparent in early vegetative stage, while

during the flowering stage translocation amongst tillers

was negligible (IRRI, 1965, 1971 , Yin, Shen and Shen,1958).

The post flowering carbohydrate contribution to the panicle

was in the order of 60 to 70 per cent (Matsubayashi, 1968)

and varieties differed in their translocation of carbon

fixed at different stages of ripening. In early varieties

the translocation was more than in late varieties (Tanaka,

1966; Rao, 1970; Lupton, 1966). The movement of assimilates

appeared to be regulated by the proximity and size of the

sink (King et al., 1967). The translocation of carbo-

hydrates depended upon the nitrogen concentration (Murty, 1969)

Kumura (1957) confirmed that the best ripening was brought

about with nitrogen content ranging from 1.0 to 1.4 per cent

in the leaf blade during 30 day period commencing from the

fifth day after heading.

In most of the cereal crops the '' economic

yield '' was the product of the ''biological yield '' and

the '' harvest index ''. The biological yield referred to

total drymatter and economic yield is economically useful

part of the biological yield. The harvest index is the ratio

between the economic yield and biological yield (Nichiporovich 1954, Donald, 1962). In case of cereals like rice, harvest index is referred to as the proportion of grain weight to the total dry weight per unit land area. For attaining high yields, both dry matter production and harvest index should be high (Tanaka, 1972).

It was demonstrated by Ishizuka and Tanaka (1953) that in rice, grain yield was positively correlated with dry matter production during ripening, and major part of the starch in grains at harvest was the photosynthetic product of the leaves which was translocated directly to the developing grains after flowering. Hence the spikelet number and spikelet size formed the '' sink '' of the carbohydrates while the '' source '' of carbohydrates was contributed by the magnitude of photosynthesising tissue, and its photo-synthetic rate. Tanaka (1972) reported that the terms the '' source '' or the '' sink '' expressed potential. The dry matter production during grain filling is the result of interaction between these two potentials. If one was limiting the other could not express its full potential.

In rice, Murata (1969) gave three examples for the relative importance of yield capacity and assimilate supply for grain yield (a) yield capacity limiting (b) assimilate capacity limiting and (c) yield and assimilate capacity well balanced.

Tanaka, (1972) also visualised the above examples and laid emphasis on the importance of grain to straw ratio for higher grain yields in rice.

Watson (1951) reached the conclusion that variation in leaf area and leaf area duration was the main cause of differences in yield; variation in net assimilation rate was of minor importance. In other words the area of the leaf was more important and phosynthetic efficiency per unit leaf area was of secondary importance.

However, in recent years considerable differences were noticed in the photosynthetic efficiency among species and amongst varieties within a species (Murata, 1970). Hence the parameter of photosynthetic efficiency cannot be eliminated for determination of the over all efficiency of source i.e. leaf. A positive correlation between the photosynthetic efficiency and leaf thickness in rice was evident (Murata, 1970; Murty, 1970; IRRI, 1970) and such simple characters may be helpful in identifying varieties efficient in this useful physiological trait(Murty et al 1970; Moss and Musgrave 1971).

Increased photosynthesis of rice community with increase in light intensity until 70 - 90 K lux was reported (Murata, 1961; Takeda, 1961; Tanaka et al., 1966; Tanaka et al., 1969; Togari et al 1956). A close positive correlation of rice yield with the amount of solar radiation during the period from reproductive stage to maturity was noted by De Dutta (1970); Munakata et al. (1967) and Murata (1964).

Hence the duration of ripening period was an important character for higher grain yields. Correlation between longer duration of grain filling period and higher yield in rice and corn was reported by many workers(Allison et al 1966; Daynard et al.,1971; Tanaka et al.,1967; Tsunoda, 1964).