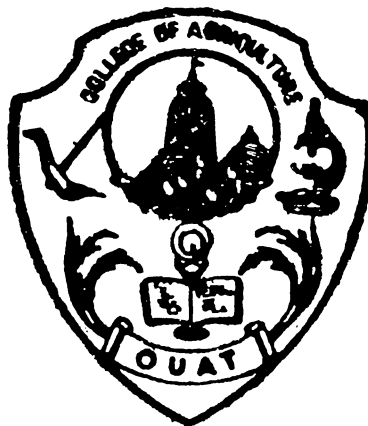


EFFICIENCY OF WATER MANAGEMENT UREA AND SUPER GRANULE UREA IN RICE DURING SUMMER SEASON

A
THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
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By

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BHUBANESWAR
1983

THESIS ADVISOR :

K. C. DAS.

Dedicated To
My
Beloved Parents

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Ex-Reader, Department of Agronomy,
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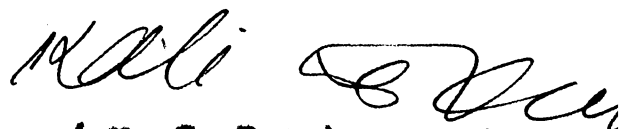
Bhubaneswar,

Dated, the May, 1984.

C E R T I F I C A T E

This is to certify that the thesis entitled
"EFFICIENCY OF WATER MANAGEMENT UREA AND SUPER GRANULE
UREA IN RICE DURING SUMMER SEASON" submitted in partial
fulfilment for the award of degree of MASTER OF SCIENCE
IN AGRICULTURE (AGRONOMY) of the Orissa University of
Agriculture and Technology, Bhubaneswar, is a record of
bonafide research work carried out by Sri Khitish Chandra
Pradhan under my supervision and guidance. No part of
the thesis has been submitted for any other degree or
diploma or published in any other form.

It is further certified that such help or
source of information, as has been availed of, during
the course of investigation, has been duly acknowledged
by him.


(K. C. Das) 25/5/84

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CHAPTER - I
INTRODUCTION

INTRODUCTION

The alleged stagnation of rice productivity in eastern India including Orissa has been very often attributed mostly to inefficient water and fertilizer management practices in both kharif and Rabi seasons. Of the 4.2 million hectares of rice grown in Orissa 3.36 million hectares is rainfed. During summer only 1.65 lakh hectares is put to rice due to availability of irrigation in different irrigation projects.

Inefficient water management practices in these areas has increased water logging and its attendant problems of increased disease and pest incidences. Nevertheless, the fertilizer use efficiency is the least being about only 10 - 12 kg grains per kg of nitrogen. The fertilizer consumption is also abysmally low i.e., only 9.9 kg nutrients per hectare as compared to 123.7 kg in Punjab and 45.5 kg in Haryana (1981-82), the non-traditional rice growing areas. The high productivity of rice in these areas has been attributed to high fertilizer use and efficient water management practices.

The efficiency of nitrogen in the rice field depends upon the form, the time and the method of application. The microclimate of rice fields that remain either submerged or saturated throughout, encourages

leaching, nitrification and denitrification of nitrogen. Results available show that the fertilizer nitrogen use efficiency is only 30 % (33 - 53 %, Westfall, 1969; 33 - 61 %, Reddy and Patrick, 1976; 11 - 27 %, Upadhy et al., 1974; 33 - 57 %, Racho and De Datta, 1968; 10 - 80 %, Sanchez and Calderon, 1971; Khind and Datta, 1975) which can be increased to 55 - 60 % (Broadbent and Mikhelsen, 1968; De Datta et al., 1974) under controlled conditions. Reduction of loss through selection of fertilizer, its time and mode of application will result in saving of fertilizer nitrogen and increasing the efficiency of applied fertilizer. It is claimed that application of urea in the reduction zone and/or as urea forms to reduce the rate of rapid rate of availability so as to increase the opportunity period of rice to absorb it gradually for a longer period will increase the efficiency and production.

Efficient water management consists of applying the required quantity of water for the crop during its growth period as per evapotranspirative demand of the atmosphere and to reduce the unavoidable losses like seepage, deep percolation and special requirements to the minimum. Earlier studies indicated that in the rice field the total water requirement constitutes 12 - 15 % towards evaporation, 28 - 30 % towards transpiration

(Lenka, 1976, 1978) and the rest towards deep percolation and seepage which can be minimized by reducing the depth and/or increasing the frequency of water application. Under suitable water management practices the water requirement of rice can be reduced to 60 - 70 cm and the efficiency of water utilization increased. The pathway analysis of rice yields indicates that about 75 % of the yield is attributed to number of effective tillers per unit area, 12 - 13 % to length of panicle, 8 - 9 % to number of grains and 6 - 7 % to 1000-grain weight (Lenka, 1973; Murty and Murty, 1978). In many cases the contribution of 1000-grain weight has been found to be less than this also. Since these yield attributing characters are formed and determined at different stages of growth, and depend very much on nutrition and moisture availability, adequate supply of these two factors at the respective stages appear most important. Most of the effective ears are borne within thirty-five days after transplanting. Keeping land submerged to a greater degree during this period reduces tillering. Reduction of moisture content during successive stages affects panicle characters and reduces yield. Hence, maintenance of soil moisture as required for the maximum yield attributing characters is felt essential. Besides increasing yield per unit area, adoption of suitable water management

practices has also its role in increasing the ayacut efficiency bringing more area under cultivation and solving the tail end problems. Keeping these in view an experiment was conducted during dry season under Bhubaneswar conditions to find out:

- 1 suitable water management schedule for the medium duration rice,
- 2 whether standing water is necessary throughout or during a part of the life period of rice crop,
- 3 depth of irrigation and time of drainage,
- 4 phasic and total water requirement of the crop and
- 5 the response to nitrogen and the effect of urea, incubated urea and supergranule urea in nitrogen absorption and utilization efficiency.

CHAPTER - II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In modern rice culture, water management, one of the most important cultural practices involves manipulation of water supply in adequate quantity at the time of need and draining excess quantity when not necessary. Water management, thus, involves irrigation, drainage and its conservation. In this chapter an attempt has been made to review the available literatures on water management in rice, particularly in dwarf indicas.

1. Concept of Water and Irrigation Requirement of Crops

The term "water requirement" used in plant physiology refers to ratio of the quantity of water transpired by the crop during its growth period to the weight of dry matter produced (exclusive of roots) and is otherwise known as transpiration ratio (Briggs and Shantz, 1913). This concept of water requirement gives only a measure of water lost through transpiration and does not provide any account of other losses. In practice, a considerable quantity of water is lost by evaporation from the soil surface of the cropped area in addition to the transpirational loss. Therefore, both these losses collectively represent the actual quantity of water used up by a crop and is termed as "Evapotranspiration"

(Thornthwaite, 1948). Some quantity of water is also used up for metabolic processes. The total quantity of water used ($E + T + Mu$) is known as "Consumptive use" (Cu or U). Since water used for metabolic processes constitutes a very small portion of the total water used, evapotranspiration being the major component is generally used as the best index of consumptive use. Besides, during the process of ET in the field, some amount is unavoidably lost due to seepage and deep percolation. Hence for all practical purposes, ET and all other losses represent water requirement.

Therefore, water requirement as 'demand' and the 'supply' and would consist of contribution from any of the sources of water, the major ones being the irrigation water (IR), effective rainfall (ER) and soil profile contribution (S) including that from shallow water table. The portion of water required by the crop from the irrigation is called the irrigation requirements ($WR - \text{Rainfall} - \text{contribution from other sources} = IR$).

Water Requirement of Rice

The water requirement of rice has been found to vary with the season, duration of the variety evaporative demand of the atmosphere, topography, the soil type, water table depth and the cultural practices followed.

Detailed work on water requirement of dwarf indica rice in India started consequent to introduction of high yielding varieties in 1965. The earlier work reported were on rice varieties like Taichung Native 1 and IR 8. The water requirements of rice variety IR 8, during dry season were 910, 804, 850, 832, 695 and 197 mm under deep continuous flooding, shallow continuous flooding, intermittent drainage + flooding, alternate irrigation and flooding, alternate irrigation and irrigation at moisture stress, respectively (De Datta and Williams, 1968). The water requirement of TN 1 at Bhubaneswar was 1131 mm of which 40 mm was from transplanting to maturity (Lenka and Bhol, 1972). During dry season, the water requirement of TN 1 was 729, 1314 and 1071 mm under saturated, submerged (6 - 7.5 cm) and alternate wetting and drying conditions, respectively (Lenka, 1971). The water requirement of 'Bala' (104 days) in wet season at Chakuli, was 296 mm under continuous saturation and 620 mm under continuous submergence (Lenka, 1976).

Excluding 200 mm required for nursery and puddling, water requirement for Cauvery (96 days), Bala (104 days), TN 1 (113 days), Padma (108 days), Ratna (111 days), IR 8 (135 days), Jaya (125 days) and Jagannath (152 days) were 410, 430, 450, 530, 490, 930, 840 and 1150 mm, respectively, during Kharif season (June - November)

characterised with high humidity, moderately high temperature and high water table conditions leading to accumulation of water in the rice field and reduction in seepage and deep percolation losses. But due to high evaporative demand and low water table, water requirements Rabi season (January - May) were more and were found to be 730, 1020, 960, 900, 1160 and 1360 mm for Bala (118 days), TN 1 (138 days), Padma (119 days), Ratna (124 days), IR 8 (148 days) and Hema (146 days), respectively (Lenka, 1976). Water requirements from transplanting to tillering, tillering to flowering and flowering to ripening were 237, 300 and 293 mm for TN 1 and 245, 250 and 395 mm for IR 8, respectively (Lenka, 1971).

The consumptive use of water was found to be 729, 803, 808, 798 and 790 mm for different agro-climatic zones of Uttar Pradesh (Garg and Mehrotra, 1973). The water requirement was 2828 mm when the treatment 10 cm submergence to soil cracking was given and it was more than this by 17.4 and 9 % in the treatments saturation to field capacity and 5 cm submergence to saturation, respectively (Kumar and Singh, 1978). For the variety Indira (97 days) water requirements was found to be 475 mm in plots kept saturated throughout and 736 mm in plots kept flooded throughout (Lenka and Singh, 1977).

Effects of Submergence/Flooding

Necessity of submergence/flooding has been found to be a function of water table depth. Continuous submergence as a traditional method has been considered beneficial because it (i) controls and eliminates weeds (Ramiah, 1977), (ii) regulates temperature of the soil and plant (Bhattacharya, 1972), (iii) aids in growth processes, particularly in photosynthesis due to reflection of light to the lower leaves (Dastane and Nelliet, 1970), (iv) helps in absorption of nutrients, particularly, N, P, K, Fe, Mn and Silica (Bhattacharya, 1972), and as such safeguards against uncertain water supply (Vamadevan, 1973). In strongly acid soils flooding increases availability of Fe and P, especially in the reproductive phase and suppresses Mn toxicity (Pande and Mittra, 1970; IRRI, 1976). The concentration of water soluble Fe varies from 0.1 ppm shortly after submergence to as high as 600 ppm and in acid sulphate soils the concentration may go up to 5000 ppm within a few weeks after submergence (Ponnampersuna, 1976). The content of iron in flooded rice roots was about 10 times more than in shoots (Yoshida and Takahashi, 1958). Strongly acid soils with adequate amount of organic matter and reactive iron oxides can build up toxic concentrations of ferrous iron and thereby cause iron toxicity problems

in submerged ultisols, oxisols, and acid sulfate soils in the tropics (Ponnamperuma et al., 1973).

The content of N, P and K in grain and straw increased due to submergence (Chaudhury and Mc Lean, 1963; Enyi, 1963; Pandey, 1976; Lenka et al., 1976 and Moturi, 1977). But in sandy loam soil with high permeability the concentration of Fe, Mn and K has not been found to be influenced by 3.5 cm standing water under Chakuli condition (Lenka and Sahu, 1976). Similarly, in Tungabhadra black soils continuous submergence of 5 - 10 cm has not yielded any differential effect on accumulation of Fe and Mn either in root or in stem.

Saturation Versus Submergence

Results of continuous saturation, flooding to different depths or combination of both at different stages of growth are most conflicting, possibly, due to confounded effect of duration of varieties, water table and season of cultivation (high or low evaporative demand). Under high water table conditions that generally prevail in the Kharif season due to heavy rainfall and standing water present in vast stretches of land, saturation has been found as effective as continuous submergence. But in case of dwarf and tall indica of longer duration

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maturing as late as in November and December when there is no rainfall and water table has already receded the crops have been found to respond to flooding. In summer season when water table is low and evaporative demand of the atmosphere is high, continuous shallow submergence invariably has been found more beneficial. In case of short to medium duration varieties of rice maturing by mid October, saturation has been proved as good as and also more efficient than complete submergence (Lenka, 1976).

Grist (1959) reported that moisture status as at field capacity provided adequate physico-chemical environment conducive for rice growth. Intermittent drying and irrigation every third day (Ghosh et al., 1968; Rajale and Prasad, 1975) or moisture content maintained at field capacity (Moolani et al., 1968) proved better than flooding. Saturation till 40 days after transplanting and submergence of 3 - 5 cm thereafter was found conducive both for vegetative and reproductive growth and yield of grain and straw and was equally efficient as continuous saturation and better than continuous submergence (Lenka et al., 1976). Between the two soil moisture treatments, soil saturation throughout the growth period and 5 cm standing water throughout, the difference in rice yield were not significant in Kharif season; but in Rabi season 5 cm standing water gave significantly more yield as

compared to saturation treatment (Krishna Murty, 1978). Saturation treatments created more weed problem than submergence treatments (Moturi, 1977). Yield of rice reduced by 16 - 32 % when the plants were subjected to continuous submergence/flooding at tillering stage due to a reduction in panicles/unit area when compared with saturation treatment (Rai and Murty, 1977). However, Sharma and De (1976) reported paddy yields were higher under continuous submergence than saturation. Flooded conditions resulted in a great increase in the total root porosity, transpiration, nutrient uptake and dry matter production as compared to field capacity (Saha et al., 1973).

In both aus (April - May) and boro (January - April) seasons, the grain yield of TN 1 was more under submergence (3 - 5 cm) than under saturation in an acid lateritic soil (pH 5.4) at Khargpur (Pande and Mitta, 1970). At Bhubaneswar submergence with 5 cm water throughout the crop growth period was found the best for Jaya (Rao, 1971). Maintenance of moisture at saturation to field capacity till tillering and 3 - 5 cm submergence thereafter till ripening for TN 1, IR 8, CR 26-25, Bala, Cauvery, Ratna, Jaya and Hema in both the seasons proved better than continuous submergence under high water table condition (Lenka, 1976).

Submergence of 3 - 5 cm or deeper appeared linked with higher evaporative demand. Under conditions of low evaporative demand, as prevailing during monsoon season, submergence was found not necessary and proved as good as or better than continuous saturation or their combination (Dastane et al., 1970); Pande and Mitra, 1970; Lenka, 1971; Ghildyal, 1972; Rai and Murty, 1977 and Talha et al., 1980).

In general, submergence greater than 10 cm was found detrimental to the rice crop (Yamada, 1965). High yields and high water use efficiency can be achieved with continuous shallow water of 2.5 cm (IRRI, 1967). Dastane et al. (1971) also observed that a depth range of 0 - 4 cm of water seemed to be optimum for rice crop. Excess water above 4 cm was of no advantage for most of Indian varieties and was, particularly, harmful to dwarf indica varieties.

Effects of Drainage

Drainage aids in much needed soil aeration and is beneficial for (i) protection against lodging by preventing overassimilation of nitrogen and (ii) prevention of reductive process at the soil water interface, which hampers the assimilation of plant nutrients (Bhattacharya, 1972). Intermittent midseason drainage has been practised

under Japanese conditions to reduce the deleterious effects of reduced condition due to continuous stagnation of water. This also helps increasing the soil temperature to invigorate the activity of the roots and rhizosphere microflora, since the oxidative power of the roots decreases with the crop age - it is maximum at tillering and the least at ripening (Okajima, 1964). It is not clear whether allowing the water depth to reduce to the level of saturation brings similar effect (Matsubayashi et al., 1965 and Ponnampereuma, 1981). Removal of anaerobic toxins and carbon dioxide is a distinct advantage of midseason drying of some soils (Ponnampereuma, 1971). Another advantage is regulation of nutrient supply to the crop, particularly nitrogen supply at the later stages, to suppress growth of late tillers.

Alternate wetting and drying or irrigation whenever soil starts cracking or keeping the soil saturated till flowering and maintaining 5 - 8 cm water thereafter was found to save 40 - 50 % water as compared with submergence throughout (Rao et al., 1971 and Lenka, 1971). By draining the field 30 to 40 days after planting, 20 % increase in yield was obtained at CRRI (Rao et al., 1971). Drainage increased vegetative growth and grain yield on strongly acid soils by depressing the concentration of water soluble CO_2 and Fe^{++} , oxidisable matter and

organic acids (IRRI, 1966) and reduced yield (Sharma and De, 1976).

Drainage at any stage of the crop growth has been found to exert both beneficial and detrimental effects; the evidences, however, being more in support of the former. The adverse effects, generally attributed to drainage, are due to development of moisture stress on drying.

Delayed flowering, very high percentage of sterility and low P and Mn contents of plants were associated with prolonged drainage (Chaudhury and Mc Lean, 1963). Reflooding the soil after aeration (drying) for several days caused pronounced decrease in the uptake of nitrogen by the rice plant as a result of denitrification (Patrick et al., 1967). Rice field with moisture below saturation level for more than three days at a stress had shown significant reduction in yield (Dastane et al., 1970). Drainage at pre-tillering stage was found to be conducive to crop growth (Bhattacharya, 1972). Other disadvantages include possible root pruning caused by soil shrinkage, the reversal of beneficial pH changes, and increased loss of nitrogen (De Datta and Abilay, 1973).

Water Use Efficiency

The water use efficiency in rice has been found to vary with the season and water management practices. In most cases the assessment is not free from inaccuracy due to intermittent rainfall in the Kharif season and unprecised ultimation of deep percolation and seepage in either season.

The water use efficiency (g l^{-1}) was found to be 1.1, 1.2, 0.7, 1.4 and 0.6 when the crop was subjected to intermediate continuous flooding (7.5 cm), shallow continuous flooding (2.5 cm), deep continuous flooding (15 cm) + drainage at maximum tillering, continuous soil saturation (1.0 cm), deep continuous flooding (15 cm), r respectively during dry season (De Datta and Williams, 1968). In another experiment having the water management schedules like midseason drainage, deep continuous flooding, shallow continuous flooding, intermittent drainage + flooding, continuous flowing irrigation, alternate irrigation and flooding and alternate irrigation, during dry season the water use efficiency found out by the above authors 0.98, 0.93, 1.02, 0.90, 0.18, 0.90 and 1.03 g grain/litre of water. Jha et al. (1974) reported that irrigation at the hair cracking stage supplemented by an irrigation at the flowering stage reduced water requirement and

percolation losses and gives the highest water use efficiency with only a small reduction in paddy yield. The water use efficiency was 4.06, 4.98 and 4.94 kg paddy per hectare mm with the treatments saturation to field capacity, 5 cm submergence to saturation and 10 cm submergence to soil cracking (Kumar and Singh, 1978). The water use efficiency increases with increase in nitrogen rate and was higher with soil saturation maintained throughout the growth period than with other moisture regimes (Iruthiyaraj and Morachan, 1978). Shih (1981) reported the average water reducing to produce 1 kg grain was 750 - 1140 litre and spring, summer crops used more water than autumn crops. The best method was to maintain a shallow water level which gave 0.79 and 0.83 water use efficiency (g/l) comparing with a height of 7 and 12 cm which gave 0.64 and 0.66 with stagnant water and 0.32 and 0.33 efficiency with running water (Sachet, 1982). Jha *et al.* (1981) scheduling 7 cm irrigation 2 to 3 days after the disappearance of ponded water resulted in paddy yield similar to those obtained with continuous or partial flooding, but saved 37 - 44 % of the irrigation water and increased the water use efficiency by 49 - 77 %. The alternate wetting and drying gave the high water use efficiency of 52 kg paddy/ha cm water used (Subramanian *et al.*, 1978).

NITROGEN

Nitrogen is the most important nutrient for rice crop not only for its major influence on the growth and reproduction but also for its recurrent heavy demand under high rainfall and tropical conditions. Fertiliser nitrogen applied to soils undergoes numerous physico-chemical transformations. The recovery of fertilizer nitrogen of rice is frustratingly low and is deterrent for getting the potential yields from the modern high yielding varieties. Various approaches employed to minimize nitrogen losses include agronomic practices involving split application at the important growth stages where it is utilized efficiently, time of application and the method of application. These are quite important for efficient utilization of nitrogen. Another practice found attractive along with the proper timings of nitrogen application to minimize losses due to nitrification, denitrification and volatilisation of ammonia is the placement of fertilizer nitrogen in the reduced zone so that nitrogen remains available at a slower rate over a longer period of time and the efficiency of nitrogen increases. An effort has been made in the following section to review briefly some of the findings relevant to the present study.

Phasic Requirement of Nitrogen

The important stages of growth in the life cycle of rice crop are tillering, panicle initiation and ripening. The requirement of nitrogen in these stages of growth is found to be different. Ishizuka (1932), using a short term variety in Hokkaido, in northern Japan, demonstrated that nitrogen was required for the first 9 weeks (at least 7 weeks) from the 7th day after germination. Thereafter, nitrogen starvation did not affect yield. Osugi et al. (1938), using a mid term variety, found that during the 1st six weeks, a one-week nitrogen starvation did not affect yield; however, 2 weeks of starvation obviously decreased it. Nitrogen starvation at the later stages did not affect yield if nitrogen had been supplied for 9 to 13 weeks at the early growth stages. He also confirmed that an optimum nitrogen concentration for obtaining high grain yields at different stages of growth was 40 ppm or less for 3 weeks after transplanting (tillering stage), 40 ppm or more for the following 6 weeks (late tillering, panicle initiation, and panicle development stage), and 40 or 20 ppm for the last several weeks (flowering and ripening stage). Using a mid term variety in Tokyo, Kasugai (1939) found that nitrogen starvation hardly increased yield in the growth period 2 months following transplanting and that earlier

nitrogen starvation caused a worse effect on grain yield. Working with an indica variety in India, Tanaka et al. (1959 a) found two peaks of partial efficiency in the series of low nitrogen level (10 ppm), the first peak occurring during the vegetative stage about 35 days before flowering and the second peak occurring just after flowering. In the high nitrogen level (60 ppm), only one peak period of partial efficiency occurred at the early stages of growth, about 50 days before flowering. Tanaka et al. (1959 b) also examined at Cuttack the nitrogen uptake of tall indica varieties of different maturation periods and found two peaks in the rate of nitrogen uptake, one at the maximum tillering stage and the second at the panicle development stage. On this basis, from the above findings it is concluded that nitrogen requirement of rice plant is seen to be high at the maximum tillering stage and again at the ear development stage.

Nitrogen Requirements at Different Growth Stages in Relation to the Determination of Yield Components

Rice yield being a function of number of tillers per unit area, length of panicle, number of grains per panicle and their weight, depends heavily on concentration of nitrogen in the soil, its absorption, translocation and

utilization in plant parts. Since these yield determinants are formed at different stages of growth and the critical concentration of nitrogen favouring their growth and development are different, application of nitrogen corresponding to these important stages of growth are of paramount importance. Tillers, panicle length, number of grains and 1000-grain weight contribute 75 %, 12 - 13 % and 89 and 3 - 5 % to the final yield (Lenka, 1973). Kumura (1956 a) studied the relationship between the nitrogen concentration and the magnitude of yield constitutional components. He obtained the results, (1) the number of tillers was strongly correlated ($r = 0.96$) with the nitrogen content in the leaf blade during the tillering period, closely resembling the results of Kuno (1943), (2) the number of spikelets per panicle was directly proportional, so far as the range of the content was between 1.5 and 3.5 percent, to the nitrogen content in the leaf blade during the period in which the number of spikelets is mostly determined (28 to 7 days before heading, as found by Matsushima et al., 1952) and (3) kernel weight increased with increasing nitrogen content up to 1.3 % in the leaf blade during the ripening stage. Kumura (1957) further confirmed that the best ripening was brought about with a nitrogen content ranging from 1.0 to 1.4 % in the leaf blade during the 30 days period commencing from fifth day after heading.

Examining the effect of nutrients on components constituting yield Kiuchi and Ishizuka (1960) stated that (1) the emergence of tillers was more favourably influenced by the absorption rate of nitrogen than by the nitrogen content in the plant during the tillering period, (2) the number of grains per panicle was closely connected with the nitrogen content in the plant during the period in which the number of grains is determined and (3) the weight of 1000-grains was favoured when the plant had nitrogen contents of 1.14 to 1.75 percent at heading time and 0.9 to 0.85 percent at maturity. Takahashi et al. (1957), however, found that during the tillering period the emergence of tillers was more correlated with the nitrogen content in the stem than with that in the leaf blade and sheath.

Oshima (1962) studied the effect of nitrogen nutrition on the tillering of the rice plant. He found that during the vegetative period the number of tillers was increased as the amount of nitrogen applied was increased; but the tiller emergence was more closely associated with the content of water soluble nitrogen in the stem than with the total nitrogen in any other part of the plant. Kiuchi et al. (1961) reported that the necessary rate of nitrogen absorption for maintaining tiller development was $1 \text{ mg day}^{-1} \text{ g}^{-1}$ dry weight of the

plant; in soil, 2 mg of nitrogen per 100 grams of dry soil was the lowest limit for developing tillers.

Matsuura (1962) also examined the relationship between the emergence of tillers and the nitrogen concentration under solution culture and said that an optimum concentration was 30 to 40 ppm and the lowest critical limit was 8 ppm.

Nitrogen Application at Successive Growth Stages

If the crop absorbs a high proportion of the nutrients added as a fertilizer, fertilizer efficiency automatically increases. This means fertilizer efficiency can be increased by getting higher yields with the same amount of nutrient absorbed by the plant. One way to achieve this is to apply the fertilizer at a time to meet the demand of the rice plant best.

Matsuki et al. (1941) reported that when a whole dosage of nitrogen was applied at each stage, the most effective stage for grain production was 10 days after transplanting. The efficiency of grain production per gram of nitrogen absorbed by the plant decreased as the growth stage advanced, showing a second maximum 40 days after transplanting (corresponding to the initial stage of panicle formation). When a half dose was applied as a base dressing and another half as a top dressing at

each stage, the most effective stage for grain production and the highest stage for efficiency of grain production per gram of nitrogen absorbed were both found 40 days after transplanting. Consequently, they emphasized the advantage of nitrogen top-dressing at the initial stage of panicle formation. Basak et al. (1962) reported top dressing or foliage spray of Ammonium sulphate and urea about 3 weeks before heading increased the nitrogen content of the grain by 28 %. Wada and Matsushima (1962) from their experiment concluded that nitrogen top dressing at full heading time increased the dry matter content for which the yield as well as the percentage of ripened grain per panicle also increased. Bredero (1965) from his experiment on shallow swamp variety indicated that nitrogen absorbed during flower initiation was fully used for an increase in grain weight. Seacher and Wells (1960) concluded that for a dose of 80 kg of N/ha in paddy, apart of the fertilizer must be top-dressed at 50 days after planting and the rest at early boot stage that is 80 to 85 days after, to get good results. Sims (1965) found that on low and medium fertility soils relatively more of nitrogen should be applied near the jointing stage. He observed that under conditions of high soil fertility, nitrogen should be top-dressed either during the early stages of crop growth, or not at all. Application

of nitrogen half at planting and another half one month later gave the highest yield than the single application (Mallik and Das, 1965).

Timing of midseason nitrogen application is highly critical for some varieties (Huey, 1977). Nitrogen applied too early will increase lodging, applying nitrogen too late will be less beneficial to yield and may delay maturity. Ghobrial (1980) reported that top-dressing at maximum tillering and panicle initiation significantly improved nitrogen use efficiency by promoting production of more panicles per unit area and by increasing grain weight. Split application of nitrogen as urea, 25 % at transplanting, 50 % at tillering and 25 % at panicle initiation is better than double or single split (Panda et al., 1977 and Roy et al., 1977).

However, working with a crop grown under ideal conditions Evatt (1969) indicated that nitrogen may be effectively applied in a single application. Evatt and Hodges (1975), suggested that if nitrogen is applied in a single dose, considerable blending with other nutrients is necessary before it is applied to the soil. A single application of nitrogen to rice 2 weeks before primordia initiation significantly increased the utilisation of fertiliser nitrogen (Serry et al., 1974).

More recent studies in India and in the Philippines suggest that two to three applications of nitrogen per crop gives the highest nitrogen efficiency and that more split applications are needed for long duration varieties and for lighter soils (Prasad and De Datta, 1979).

Recovery of Applied Nitrogen Applied
at Different Stages of Growth

The efficiency of nitrogen fertilizer uptake at different times of application can be determined by tracer techniques. In an experiment by Yanagisawa et al. (1967) in Japan, 55 % of the nitrogen applied 15 days before heading was used by the plant. At flowering, use was 49 %; at tillering, 34 %; and at transplanting as a basal dressing, 7 %. In another pastudy, the application of two-thirds of the nitrogen at transplanting and the remaining one-third at the booting stage gave higher nitrogen recovery (51 %) than when the entire amount was applied at transplanting (38 %) or when top-dressed at the tillering stage (32 %). Studies in California showed that 18 % of tracer ^{15}N was absorbed when the nitrogen was top-dressed at maximum tillering, and 43 % when top-dressed at the booting stage (Patnaik and Broadbent, 1967). Recovery of applied nitrogen was 30 - 38 and 34 - 55 kg/ha with early (23 days after transplanting) and

late (50 days after transplanting) application, respectively, when the applied nitrogen was 60 kg/ha (Reddy and Patrick, 1978).

Loss of Nitrogen in the Rice Field

Nitrogen is removed from the soil by plant but it is not considered a loss. Nitrogen losses in the soil occur mainly from (i) denitrification, (ii) ammonia volatilization, (iii) leaching, (iv) chemical fixation and retention of ammonium by soil clay minerals and amorphous materials and (v) immobilization of nitrogen by soil micro-organisms. The last two processes mentioned are often temporary and may be considered as mechanisms of temporary loss of nitrogen but could be very important from the plant nutrition point of view, particularly, on short term basis.

The magnitude of loss of applied nitrogen has been estimated as 20 - 40 % in India (Abhichandani and Patnaik, 1955), 30 - 50 % in Japan (Mitsui, 1956), 37 % in California, 68 % in Louisiana in the United States and 25 % in Philippines (De Datta, 1977). Tusneem (1970) measured losses from flooded soils using ^{15}N and reported loss as high as 68 % of the added nitrogen. Mitsui and Ota (1950) in a tracer study of nitrogen transformation observed more losses of applied $\text{NH}_4^+ - \text{N}$

when it was applied to air dried soil and then flooded than when the application was made direct to undried soil. Takijima (1959) reported the losses of nitrogen during flooded incubation conditions in the following order: urea - N, NO_3^- - N, NH_4^+ - N. The cause of loss of nitrogen from urea was presumably due to volatilization by alkaline reaction of the soil, while NO_3^- and NH_4^+ were lost mainly through denitrification.

Large losses of nitrogen as high as about 20 % of the total nitrogen or 400 lbs per acre occurred as a result of several drying and flooding cycles. The major portion of this loss took place during the 1st two to three cycles. These studies provide an indirect evidence of loss of nitrogen due to nitrification-denitrification. The losses resulted in reduction in yield and uptake of nitrogen by the rice crop under both green house as well as field experimental conditions (Patrick and Wyatt, 1964).

Severe losses of fertilizer nitrogen have been reported under fluctuating moisture conditions. Patrick and Tusneem (1972) reported that losses of nitrogen can occur not only under alternate wetting and drying but also under continuously flooded soils mainly due to nitrification-denitrification. Prasad and Rajale (1972) observed that urea nitrogen was rapidly lost

under wetting and drying though it was well conserved at field capacity and continuously flooded conditions in a laboratory study with a sandy clay loam soil.

Studies carried out in Japan estimates an average loss of about 20 kg N/ha every year through leaching from rice fields (Yatazawa, 1977). Similarly, Koshino (1975) concluded from the review of the literature on field lysimeter studies conducted during the past 50 years in Japan that the leaching losses ranged from 3 to 25 percent of the applied fertilizer nitrogen. In India, Panide and Adak (1971) reported that in paddy soils, the losses due to leaching could be from 45 - 60 percent from the basal application but these losses were reduced to 11 - 33 % from split application of nitrogen. Sahu (1968) on the basis of his study on efficiency of different forms of nitrogen concluded that in light acid sandy soils of low cation exchange capacity leaching may be effective after its conversion to ammonium and nitrate. In low land conditions loss of ammonium was minimum and it was held by clay micelle but the nitrate was mainly attached. There was no considerable influence of watering schedule on the nitrogen loss through leaching since most of the nitrogen was lost generally through the first leachate. The nitrate nitrogen was more leachable than the amide form followed by ammonical nitrogen ($\text{NH}_4\text{-N}$)

(Ghosh and Sharma, 1976). Padmaja and Koshy (1978) observed from a particular experiment that about 70 % of the applied nitrogen in the form of urea was lost when draining was done on the same day of manuring, that the loss was reduced to 44 % after 48 hours and that it was negligible after 5th day of fertilizer application. They opined that the heavy loss was due to weak bondage of urea - N with the soil and its free movement in the soil water. However, it is quickly hydrolysed to NH_4^+ in most soils which is either absorbed or gets itself fixed by the clay colloid.

Efficiency of Nitrogen Utilized in Rice Field

There are many reports about the low efficiency of applied nitrogen under flooded rice soils. Westfall (1969) estimated that in the United States rice areas, the fertilizer recovery ranges from 33 to 53 % with the rates of 40 to 120 kg N/ha. Racho and De Datta (1968) reported a maximum efficiency of 33 percent for application of 30 kg N/ha in the wet season and 57 percent with the rate of 90 kg N/ha in the dry season in the Philippines. These studies point out great losses of nitrogen under flooded rice soil conditions though these authors have not evaluated in detail the mechanisms of nitrogen loss although it is assumed that denitrification,

leaching and immobilization are the most important process involved. Reviews of De Datta and Magnaye (1969) and Sanchez (1971) bring out that the losses of applied nitrogen under flooded conditions are quite high and these result in lower efficiency.

Volatilization loss varied from 0.93 to 49.43 %, higher in saline soils and the lowest in black soils (Singh and Mishra, 1972). Loss of ammonia through volatilization increased with the rate of urea applied, the loss ranged from 0 to 66 % with the increasing rate of nitrogen applied from 2.8 to 107 kg/ha. The order of magnitude of loss of ammonium through volatilization was ammonium chloride diammonium phosphate calcium ammonium nitrate ammonium sulphate ammonium nitrate urea ammonium sulphate nitrate sodium nitrate calcium nitrate (Sankaracharya and Meheta, 1971). On the basis of results from the experiment carried out at O.U.A.T., Bhubaneswar, on management of low level of nitrogen Panda (1974) reported that the loss of $\text{NO}_3\text{-N}$ and urea nitrogen was 33 and 15 percent, respectively, but there was no measurable loss of ammonical nitrogen.

Forms of Nitrogen Carrier and Their Efficiency

Nitrogen recovery seldom exceeded 60 to 70 % of applied fertilizer nitrogen. Although there are some

losses due to volatilization of nitrogen and ammonia and due to fixation of ammonia by clay mineral entrapment and by immobilization by bacteria, the principal loss results from the leaching of nitrates. These losses have prompted a search for fertilizer materials that release their nitrogen over a long period of time so that the nitrates will be absorbed by the expanding root system during the entire growing period of the plant. There are a number of proved or potential advantages of fertilizers that release their plant nutrients slowly throughout the growing season or longer. These slow release fertilizers offer potential for increasing fertilizer efficiency, decreasing cost of application due to fewer applications, minimizing losses by leaching, fixation or decomposition, eliminating or at least minimizing luxury consumption, and avoiding damage to seedlings.

Most of the slow release fertilizers are condensation products of urea and aldehydes. Horn (1979) reviewed the efficiency of various slow release nitrogen sources, viz., sulfur-coated supergranules, like sulfur coated urea (SCU), lac coated urea (LCU), urea form (urea formal-dehyde), IBDU (isobutylidene diurea), CDU (crotonylidene diurea) etc.

Of the coated fertilizers, sulfur coated fertilizers have been most widely tested for many crops including rice. In many countries the crop response to SCU was generally superior to split application of urea at the same nitrogen rate. Experiments with SCU in India gave 25 - 30 kg grain/kg nitrogen compared with 16 - 20 kg grain/kg urea nitrogen applied as a split application (Prasad and De Datta, 1979). Results from 41 experiments in seven countries showed that SCU produced 6 more kg grain/kg nitrogen than urea (Doll, 1975). The advantages of SCU have been most obvious in soils with intermittent flooding and drying. Under such conditions in Peru it was possible to produce the same crop yield with only 40 % as much nitrogen as SCU as with urea (Sanchez et al., 1973). In Indonesia, SCU was superior to three applications of urea under intermittent flooding, but under constant flooding yields with SCU and three applications of urea were more often equal (De Datta, 1978). In United States, the use of SCU did not result in increased rice production or higher nitrogen efficiency in comparison with split applications of regular fertilizer grade urea (Westfall, 1972).

Field experiments in Japan showed that a single dose of IBDU gave 20 % more rice than ammonium

sulphate applied in split application, and 25 % more yield than ammonium sulphate applied in a single basal dressing (Hamamoto, 1966). Results with IBDU in India and Philippines were equally promising (Prasad and De Datta, 1979). In field experiments during 1967-1972 in the United States, Wells and Shockley (1975) also observed that IBDU was a suitable nitrogen source for rice.

During the Kharif (wet) season in 1978, at several locations varying in agro-climatic conditions, AICRIP evaluated urea briquettes (UB, 0.75 and 2.5 G each). The average increase recorded was 6.5 kg grain/kg nitrogen added at a fertilizer application rate of 60 kg N/ha.

Role of Urea Supergranules in the Nitrogen Economy of Rice

In so far as rice yield response is concerned, numerous field trials have demonstrated the superiority of USG over conventionally applied prilled urea.

In the field experiments to evaluate wet land rice response to deep placement of USG, Craswell et al. (1981) found that the apparent recoveries of fertilizer nitrogen in the plant were 75 % in the dry season and 85 % in the wet season. Similar increases in nitrogen

recovery were reported by many workers (Yamada et al., 1979, Li and Chen, 1980, Prasad and Prasad, 1980 and Chen and Zhu, 1982). Savant et al. (1982) observed that the fertilizer recovery in the wet land rice plant tops was significantly higher for deep placed 15_N as USG (50 - 60 percent) than for split applied urea 15_N (25 - 34 percent). They also observed that plant recovery at final harvest tended to increase as the placement depth of USG increased from 5 cm to 15 cm. Juang (1982) from Taiwan in field trials reported deep placement of USG gave a nitrogen recovery of 30 % higher than ordinary urea. The losses due to volatilization and leaching was less as compared to ordinary urea.

In about 50 percent of the field trials conducted in 13 countries during wet and dry seasons, deep placement of USG gave significantly higher yield than those derived from split application of urea (Craswell and Vlek, 1982). At 36 kg N/ha, the average yield response to deep placement of USG was 8.0 kg of rice per kg nitrogen higher than that when split nitrogen applications were used (IFDC, Annual Report, 1979). Juang (1979) reported that in Taiwan rice yields due to use of USG were higher than those due to split applied urea (1/3 at transplanting, 1/3 at maximum tillering

and 1/3 at panicle initiation stage). The effect of deep placement of USG on growth and yield of rice has been studied by Marumoto et al. (1983) in Japan and reported single deep placement of USG better than splitting of urea. The results of the field experiments conducted at IARI for four years (1977-1980) USG significantly increased grain yield of rice as compared with that obtained from ordinary urea (Prasad, 1982). Murthy and Pillai (1980-81) from Hyderabad (AICRIP) trial reported grain yields of 5.94, 6.26, 5.71 and 5.28 t/ha were obtained when 1, 2, 3 and 4 number USG/hill were applied, respectively. Similar results were obtained in other sites in India in the wet season of 1980-81. From the AICRIP data, Pillai (1981) concluded that about 25 - 30 % of nitrogen can be saved by using USG maintaining the same rice yields. Vijayachandran and Devi (1982) recorded highest paddy yield from USG as compared with urea, urea (splits), lac coated urea, urea + nitrogen serve, urea + rubber cake and urea formal-dehyde.

Effect of Water Management Practices and Nitrogen Management on the Growth and Yield of Rice

1. Plant Height

Water management. The height of plants increased with increased depth of water (Ghosh and

Bhattacharya, 1959; Moolani et al., 1968; El-Aishy, 1979; Ghosh and Chatterjee, 1979). Moisture below saturation level had a stunting effect (Sahu and Rout, 1969). Tall indica, japonica indica and dwarf indica were reduced by 42, 39.3 and 45.8 percent, respectively, in their height when subjected to moisture stress (75 % of available soil moisture) during the vegetative growth (Rao, 1971). However, Panda, 1969; Lenka and Sahu, 1973 did not get any significant differences in the height of the rice plants from different water management schedules in dwarf indica varieties.

Nitrogen management. By application of nitrogen to dwarf indica rice there was significant progressive increase in plant height (Basu Raychaudhury, 1968; Sur et al., 1970; Seshadri et al., 1970; Rethinam 1971; Sewa Ram et al., 1973; Gopalswamy and Raj, 1977; Yogeswar Rao, 1977; Pinhero et al., 1978). There was close association between plant height and other plant characteristics in conjunction with the use of nitrogen nutrient (Hayashi and Itoh, 1962).

2. Tiller Number

Water management. The effect of submergence on tillering varied with duration and depth of submergence. Continuous submergence gave the largest number of tillers

at harvest than submergence 2 to 3 months after transplanting (Enyi, 1963; El-Aishy, 1979). Effective tillers are thicker and more numerous under flooded conditions (Chaudhury and Mc Lean, 1963; IRRI, 1970; Raju, 1980).

On the other hand, 7.5 cm of standing water was found suppressing tiller production in rice, the number of tillers decreasing with increase in water depth (Cheng et al., 1956; De Datta and Williams, 1968; Rai and Murty, 1977 and Ghosh and Chatterjee, 1979). During the Kharif season at Bhubaneswar, IR 8 had the highest number of tillers when the field was kept moist throughout the growing season (Panda, 1969).

Nitrogen management. Application of nitrogen increased the number of tillers per clump (Panda and Leewrik, 1972; Koyama and Niamsrichand, 1973). There was linear increase in number of tillers/clump in varieties like 'padma', 'Cauvery' and TKM 6 with increased rates of nitrogen from 0 to 160 kg/ha (Rethinam, 1974; Eunus and Sadeque, 1974). Significant increase in tiller number per hill was observed by application of nitrogen over that of no nitrogen control (Ram Mohan Rao et al., 1977). The number of ear bearing tillers increased with heavy nitrogen manuring in rice (Russel, 1939; Murayam, 1963; Rath, 1965; Pinhero et al., 1978; Sahu and Pal, 1982).

3. Dry matter

Water management. Increasing the depth of water from 1 cm to 10 cm increased the dry weight of plants (Cheng et al., 1956; Bhan, 1979). Valoras and Letey (1966) and El-Aishy (1979) also found increase in dry weights of straw and grain under submerged conditions. However, Rai and Murty (1977) reported water logging decreased dry matter production.

Nitrogen management. Dry matter production increased consistently with the lengthening period of nitrogen nutrition (Singh et al., 1963; Tanaka et al., 1964; Murata, 1965; Dasgupta, 1969). Dry matter production increased with increasing levels of nitrogen by increasing the photosynthesis and respiration ratio (Chinaswami and Chandrasekharan, 1977; Fageria and Wilcox, 1977). The dry matter production increased significantly in case of the tall and dwarf indica rice varieties at 60 kg N/ha and 80 kg N/ha in Kharif and Rabi seasons, respectively. Over no nitrogen control (AICRIP, 1973), Singh and Pande (1974), Sahu and Murty (1975) and Koregane and Yawalkar (1976) reported that dry matter production was proportional to increase in LAI unit and optimum point was reached with increasing rate of nitrogen.

4. Number of Panicles/m²

Water management. When the plants subjected to continuously submerged condition to a depth of 5 cm produced more panicles (Duarte et al., 1974; El-Aishy, 1979). However, Rai and Murty (1977) reported that when some varieties were subjected to continuously submerged conditions paddy yield was reduced by 16 - 32 % due to reduction in panicles/unit area.

Nitrogen management. Number of panicles/m² increased with increasing levels of nitrogen (Relwani and Ganguli, 1959; Mahapatra et al., 1966; Gopalswamy, 1970; Rethinam, 1971; Yogeswar Rao, 1977; Singh et al., 1977; Munegowda and Panikar, 1977), irrespective of spacing and soil moisture (Ramamujam and Rao, 1971; Padmaja, 1976; Subbiah et al., 1977; Venkateswarlu et al., 1978).

5. Panicle Length

Water management. Submergence increased the panicle length (Cralley and Adair, 1943; Rath, 1965 and Raut, 1966). Soil moisture stress either at vegetative or reproductive phase reduced the length of ear-head (Rao, 1971). On the other hand, Moolani et al. (1968) observed the largest panicles with irrigation at field

capacity. Effect of soil moisture was more marked in dry season than in wet season.

Nitrogen management. In japonica x indica crosses it was observed that the length of panicle increased with the increase in nitrogen levels (Srinivasulu and Pawar, 1965; Ramarajam and Rao, 1971; Sadayappan et al., 1974). Rao and Prasad (1973) reported that there was significant increase in the panicle length up to 60 kg N/ha and further increase in nitrogen application was not superior over the previous dose. This was in conformity with the results obtained by scientists of CRRI, Cuttack (1973). However, there was progressive increase in panicle length up to 150 kg N/ha at Bhubaneswar (Tosh and Misra, 1972), 120 kg N/ha (Prusty and Mishra, 1973; Patnaik and Misra, 1975) has been reported.

6. Total Number of Spikelets and Number of Fertile or Sterile Grains per Panicle

Water management. Very low percentage of fertility was found under unflooded conditions (Chaudhury and Mc Lean, 1963; Subramanian et al., 1978). Highest sterility was observed in plants subjected to stress during the vegetative phase, followed by that during grain filling (Rao, 1971). Continuous flooding gave a lower proportion of sterile florets (Crus et al., 1975).

Nitrogen management. There was significant increase in the number of grains per panicle with the increasing levels of nitrogen (Kalyankutti et al., 1968; Koyama et al., 1972; Singh et al., 1978). An increasing trend in the number of spikelets per panicle was found up to 95 kg N/ha (Rao and Prasad, 1973; Koyama and Niamsrichand, 1973), up to 100 to 200 kg N/ha Subbiah et al. (1975) and Siga and Sekiya (1976).

Increase in the levels of nitrogen increased the number of fertile grains/panicle (Dasgupta et al., 1970; Verma, 1973; Hsu and Teng, 1974; Singh et al., 1977). The number of fertile grains per panicle increased up to certain limit of nitrogen levels which helped in increasing the yield (Kumura, 1957; Hasegawa et al., 1958 and Yamagata, 1958). The chaffyness or sterility was influenced by higher nitrogen dose (Ohta et al., 1965; Gopalswamy and Raj, 1977). Singh and Mishra (1976) recorded a decreasing trend in sterile grains per panicle up to 80 kg N/ha, whereas Sahu and Mishra (1977) reported that number of sterile grains increased with increasing levels of nitrogen from 0 to 90 kg/ha. Srinivasalu and Pawar (1965) reported that though in all varieties the grain sterility increased with increasing levels of nitrogen the rate of increase was more in nitrogen non-responsive indicas than that in high nitrogen responsive jeponicas.

7. Thousand Grain Weight

Water management. Submergence increased the 1000-grain weight of rice (Patnaik, 1961 and Cruz et al., 1975). However, Moolani et al. (1968), Lenka and Sahu (1972) and Lenka et al. (1976) did not find any significant differences in the 1000-grain weight due to various water management practices involving continuous saturation and continuous shallow or deep submergence.

Nitrogen management. Thousand grain weight increases with an increased level of nitrogen (Tsui and Yen, 1964; Jennings and Sornchai, 1964; Srinivasalu and Pawar, 1965; Kalyankutti et al., 1968; Ghosh et al., 1971; Eunus and Sadeque, 1974; Singh et al., 1978). Raju and Mishra (1976) observed that thousand grain weight increased with increasing levels of nitrogen up to 180 kg/ha whereas Latchana et al. (1977) and Singh (1979) reported increase up to 135 kg and 200 kg N/ha, respectively.

8. Grain Yield

Water management. Continuous land submergence gave more yield (Rajale and Prasad, 1970; Pande and Mitra, 1970; Duarte et al., 1974). Rao (1971) found 5 cm submergence to be the best for dwarf indica rice

under Bhubaneswar conditions. But Kumar and Singh (1978) found 5 cm submergence to saturation was the best for rice yield.

On the other hand, keeping the soil moist for about 45 days after transplanting and submerging thereafter up to 5 cm till dough stage was the best during Kharif season under Bhubaneswar conditions (Lenka et al., 1971). However, Rao et al. (1971) observed 20 % increase in yield over continuous submergence by draining the field 30 to 45 days after transplanting (active tillering stage). (Alternate wetting and drying with 7.5 cm water application produced the maximum yield during dry season (Lenka, 1971; Subramanial et al., 1978). Rajale and Prasad (1975) reported better yield in alternate flooding 4 cm deep and drying to soil moisture tension of 0.33 atm than continuous flooding of 4 cm deep.)

Increasing the stress period during the vegetative phase and/or the reproductive phase decreased the grain yield (IRRI, 1969). (The length of time the plant was subjected to moisture stress was more important in determining the amount of yield reduction than the particular growth stage at which the stress occurred. Soil moisture below the saturation level for more than 3 days at a stress reduced the grain yield of rice) (Dastane et al., 1970). Irrespective of varieties and

seasons, the final length of internodes and the grain yield per plant were minimum under deficient water supply and there was a positive correlation between the relative rates of stem elongation and grain yield, which made it possible to predict the yield on the basis of stem growth much ahead of harvest (Sen and Datta, 1970).

Nitrogen management. Paddy yield increased from 2.13 to 4.49 t/ha with the application of 150 kg N/ha over no nitrogen (control) and lower levels of nitrogen application gave higher yield response per kg of applied nitrogen (Singh et al., 1977). Nitrogen ultimately increased yield provided other nutrients were not limiting (Basak and Chaudhury, 1961; Srinivasan et al., 1968; Lenka, 1969; Dasgupta et al., 1970; Khan et al., 1972; Pande et al., 1973; Sahu and Murty, 1975; Subbiah and Morachan, 1976; Gopalswamy and Raj, 1977; Munelgowda and Panikar, 1977; Rammohan Rao et al., 1977 and Venkateswarlu, 1978). Jain (1968) and Tewari and Thakur (1976) stated that nitrogen fertilization boosted the grain yield of rice significantly but there was fall in grain yield at higher dose of nitrogen which might be due to toxic conditions of excess nitrogen produced by the deficiency of zinc.

9. Straw Yield

Water management. Submergence, in general, increased vegetative growth through increased plant height, leaf size and number and hence increased straw yield as compared to saturation (Enyi, 1963; Moolani et al., 1968).

Nitrogen management. There was significant increase in straw yield with the application of nitrogen over no nitrogen control (Singh and Sindh, 1976; Rammohan Rao et al., 1977) and with increase in level of nitrogen (Srinivasan et al., 1968; Bathkal and Patil, 1968; Pandey, 1969; Eunus and Sadeque, 1974; Raju and Mishra, 1976). Purusothamma and Morachan (1974) noticed an increase in the yield of straw even up to a nitrogen dose of 375 kg/ha but Seshadri et al. (1976) noticed increase only up to 140 kg N/ha and at 175 kg N/ha there was a decline in straw yield.

10. Grain:Straw Ratio

Water management. Plants grown under continuous submergence gave the maximum and those grown under saturated condition the minimum grain:straw ratio (Enyi, 1963; Kumar and Singh, 1978; Subramanian et al., 1978; El-Ashy, 1979).

Nitrogen management. The grain:straw ratio decreased with increase in nitrogen levels (Panda et al., 1973). However, Muthuswamy et al. (1972) concluded that there was no significant influence of nitrogen levels on grain:straw ratio.

11. Protein Content of the Grain

Water management. Stress at the vegetative and maturity periods reduced the protein content of grains, while stress at the reproductive phase enhanced it (Rao, 1971). Sharma and De (1979) reported submergence to 4.0 cm and alternate wetting and drying had no significant effect on crude protein content of the grain.

Nitrogen management. The protein content in paddy increases with the application of urea both in basal and top-dressing than any other forms of nitrogen (Balanarsaiah and Rao, 1962). Increasing nitrogen rate and nitrogen application to the leaves there was an increase in the crude protein content of the grain (Sharma and De, 1979).

Effect of Water Management x Nitrogen Management on Yield of Paddy

Most of the studies on water management and nitrogen fertilisation in rice have shown that their

interaction effect were not significant, thereby indicating their additive response. In cases of standing water that increases loss of nitrogen, the expected utilization has not been spectacular since maximum growth occurs at about flowering and % nitrogen of the total quantity absorbed after flowering is relatively less. Most of results on time of nitrogen application show non-significant results which provide reasons of their non-significant interaction.

CHAPTER - III

MATERIALS AND METHODS

MATERIALS AND METHODS

1. Experimental Site

The experiment was conducted in the Central Research Station of the Orissa University of Agriculture and Technology, Bhubaneswar during the dry season (February - May, 1983).

2. Soil

Soil samples were drawn randomly from 24 different spots, spread over the whole experimental site, up to a depth of 20 cm, before the preliminary tillage operation began. Soil physical constants along with its mechanical and chemical composition as determined from the composite samples are presented in Table 1 and Table 2, respectively.

TABLE 1.1. MECHANICAL COMPOSITION OF THE SOIL

Composition	Value (percent) on air dry basis	Method employed
Sand	74.38	Bouyoucos
Silt	12.62	Hydrometer
Clay	13.00	(Piper, 1950)
Textural class - Sandy loam		

TABLE 1.2. PHYSICAL CONSTANTS OF THE SOIL

Particulars	Value	Method employed
Apparent specific gravity (at puddling) g cm ⁻³	1.58	Core sampler
Field capacity (oven dry weight basis)	16.64 %	Field Determination method (Piper, 1950)
Maximum water holding capacity (oven dry weight basis)	24.78 %	

TABLE 2. CHEMICAL COMPOSITION OF THE SOIL

Composition	Quantity on air dry basis	Method employed in the Chemical analysis
1. Total nitrogen	0.043 %	Modified Kjeldahl's Method (Jackson, 1958)
2. Available nitrogen	146.19 kg/ha	Alkaline permanganate Method (Subbiah and Asija, 1956)
3. Available P	19.4 kg/ha	Olsen's method (Olsen, 1954)
4. Available K	104.0 kg/ha	Morgan's reagent (Jackson, 1958)
5. Organic carbon	0.41 %	Walkley and Black's rapid titration method (1938)
6. pH	5.92	Glass electrode Blackman's pH meter (Jackson, 1967)

Data on chemical composition of the soil showed that the soil fertility status was medium with respect to phosphorus and was low in nitrogen, potash, organic carbon and the soil was acidic in reaction.

3. Cropping History of the Experimental Plot

The experimental plot was cropped with dwarf indica rice in the Kharif and Rabi seasons of all the four preceeding years which shows the field must have been evened out with respect to its soil fertility.

4. Climate and Season

The Central Research Station of the Orissa University of Agriculture and Technology, Bhubaneswar, is situated 65 km West of the Bay of Bengal ($20^{\circ}.15'$ North Latitude and $85^{\circ}.52'$ East Longitude) at an elevation of 25.3 m above the mean sea level. It is characterised with warm and moist climate having hot and humid summer and mild winter.

Bhubaneswar receives a mean annual precipitation of about 1490.0 mm, out of which 1325.3 mm (nearly 90 %) is received during the months from June to October and the rest 164.7 mm from November to May.

A total of 98.9 mm of rain was received during the crop season of 87 days and the quantity distributed during the vegetative, reproductive and ripening phases were 10.5 mm (33 days), 44.3 mm (27 days) and 44.1 mm (27 days), respectively. May is the hottest month with the mean daily temperature of 31.7°C (37.5°C mean maximum and 26.7°C mean minimum) and February is the coldest month with the mean daily temperature of 24.7°C (31.5°C mean maximum and 18.9°C mean minimum). The morning relative humidity varies from 93 percent in March to 83 percent in May the afternoon relative humidity being 55 and 32 % respectively (90 percent to 43 percent and 83 percent to 49 percent is the mean maximum and mean minimum, respectively). The daily evaporation ranges from 4.1 mm in the month of February to 6.8 mm/day in the month of May. Mean wind velocity ranges from 14.0 km/hr in May to 7.8 km/hr in February and the mean bright sunshine hour varies from 9.3 hours in May to 7.8 hours in February.

The weather conditions as recorded at the meteorological observatory of the Central Research Station over the months (February - May, 1983) when the experiment was in progress with corresponding average figures for preceeding ten years are presented in Table 3 and depicted in Fig. 1.

**TABLE 3. WEATHER DATA OF CENTRAL RESEARCH STATION, BHUBANESWAR FOR THE PERIOD
FEBRUARY TO MAY, 1993.**

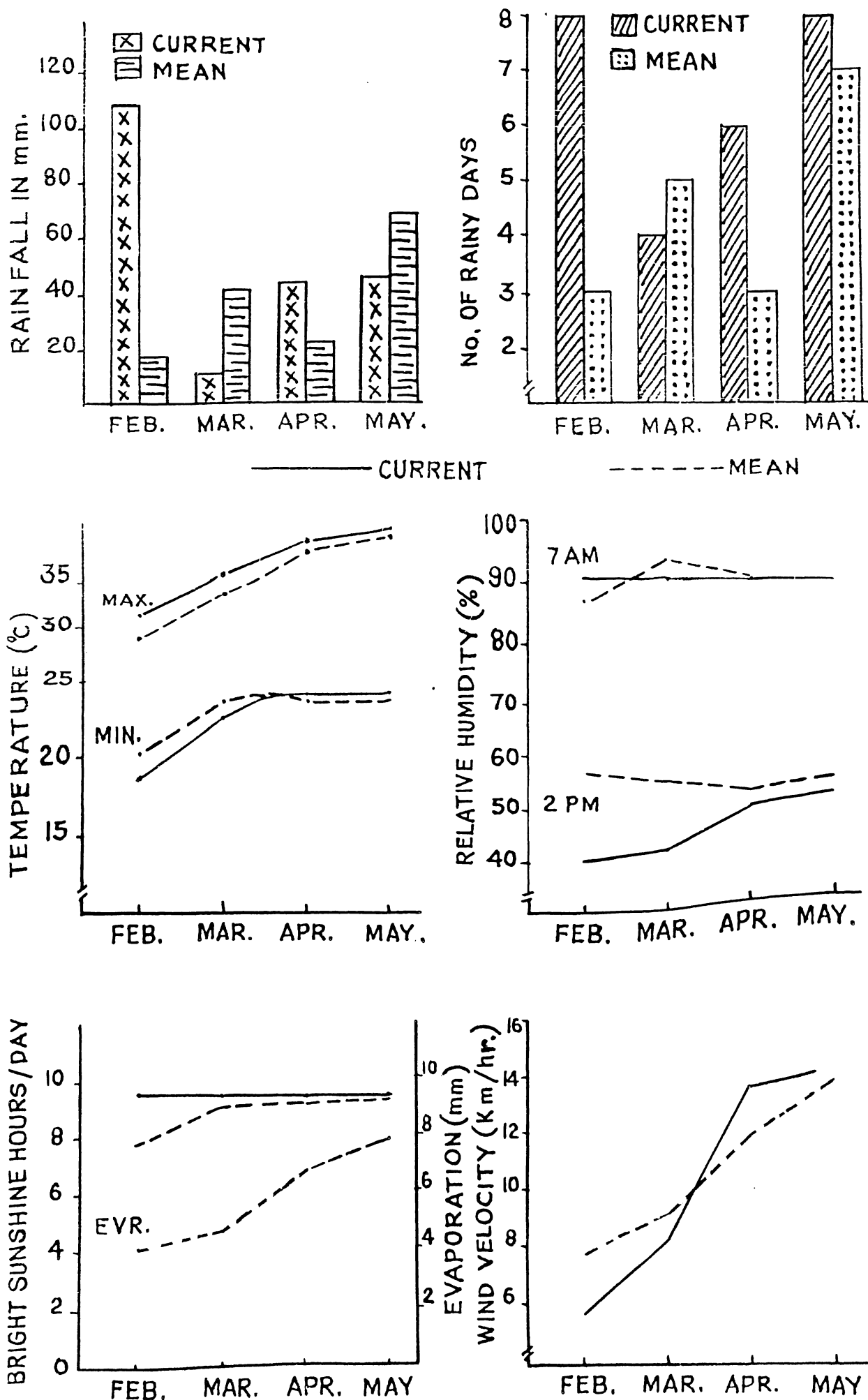
Months	Year	Rainfall in mm	No. of rainy days	Mean max. temp. in °C	Mean min. temp. in °C	Relative humidity in %		Mean wind vel. in km/hr	Mean bright sunshine hrs/day	Evapo- ration in mm/day
						7 AM	2 PM			
February	Current	108.9	8	29.2	20.2	87	57	7.8	7.8	4.1
	Mean	(18.4)	(3)	(31.5)	(18.9)	(91)	(40)	(5.8)	(9.6)	-
	D.N.	+ 90.5	+ 5	- 2.3	+ 1.3	- 4	+ 17	+ 2.0	- 1.8	-
March	Current	10.7	4	33.5	23.8	93	55	9.2	8.8	4.6
	Mean	(41.8)	(5)	(34.3)	(22.4)	(90)	(43)	(8.4)	(9.2)	-
	D.N.	- 31.1	-1	- 0.8	+ 1.4	+ 3	+ 12	+ 0.8	- 0.4	-
April	Current	44.4	6	36.0	24.9	86	51	12.0	8.8	6.5
	Mean	(22.5)	(3)	(36.6)	(25.5)	(86)	(48)	(13.8)	(9.1)	-
	D.N.	+ 21.9	+ 3	- 0.6	- 0.6	0	+ 3	- 1.8	- 0.3	-
May	Current	45.3	8	37.2	26.3	83	52	14.0	9.3	6.8
	Mean	(68.6)	(7)	(37.5)	(26.7)	(83)	(49)	(14.2)	(9.3)	-
	D.N.	- 23.3	+ 1	- 0.3	- 0.4	0	+ 3	- 0.2	0	-

Figures in parentheses indicate normal values calculated over ten years.

D.N. = Deviation from normal

The mean data on evaporation are not available.

Fig.1.WEATHER CONDITION AT BHUBANESWAR FEB.-MAY (1983)



5. Water Requirement

It is the quantity of water needed for raising a crop in a given period. It includes consumptive use and other economically unavoidable losses, i.e., seepage, deep percolation, etc and that applied for special operations such as land preparation (puddling) for transplanting.

The water requirement of the rice crop was found out by actual measurement of water irrigated to the crop during its growing period. Effective rainfall received during the growing period was also taken into account while calculating the water requirement of the crop.

$$WR = \text{Effective rainfall} + \text{Irrigation}$$

6. Water Table

To study the fluctuation of water table in the experimental plot, holes of 15 cm dia were augured to the level of free water surface, one hole in each main plot. The level of water table below the ground surface was recorded at different intervals during the crop growth period. The water table was found at a depth of 17 cm below the surface at 15 DAT. Due to accumulation of seepage water, after irrigation the level was rising to 12 cm during the early part of the season. At later

parts, it was receding even up to 40 cm below the ground level. In the saturation treatments the water table remain almost 35 cm below ground level throughout the growing season. The fluctuation of water table is illustrated in Fig. 2.

7. Soil Profile

There exists an impervious layer of hardpan 20 cm below surface extending up to a depth of 75 cm. The soil is very sticky and impregnated with coarse and fine sand. This layer has possibly been formed due to strong reducing conditions as a result of accumulation of ferrous iron and clay eluviated from the upper horizons.

8. Experimental Details

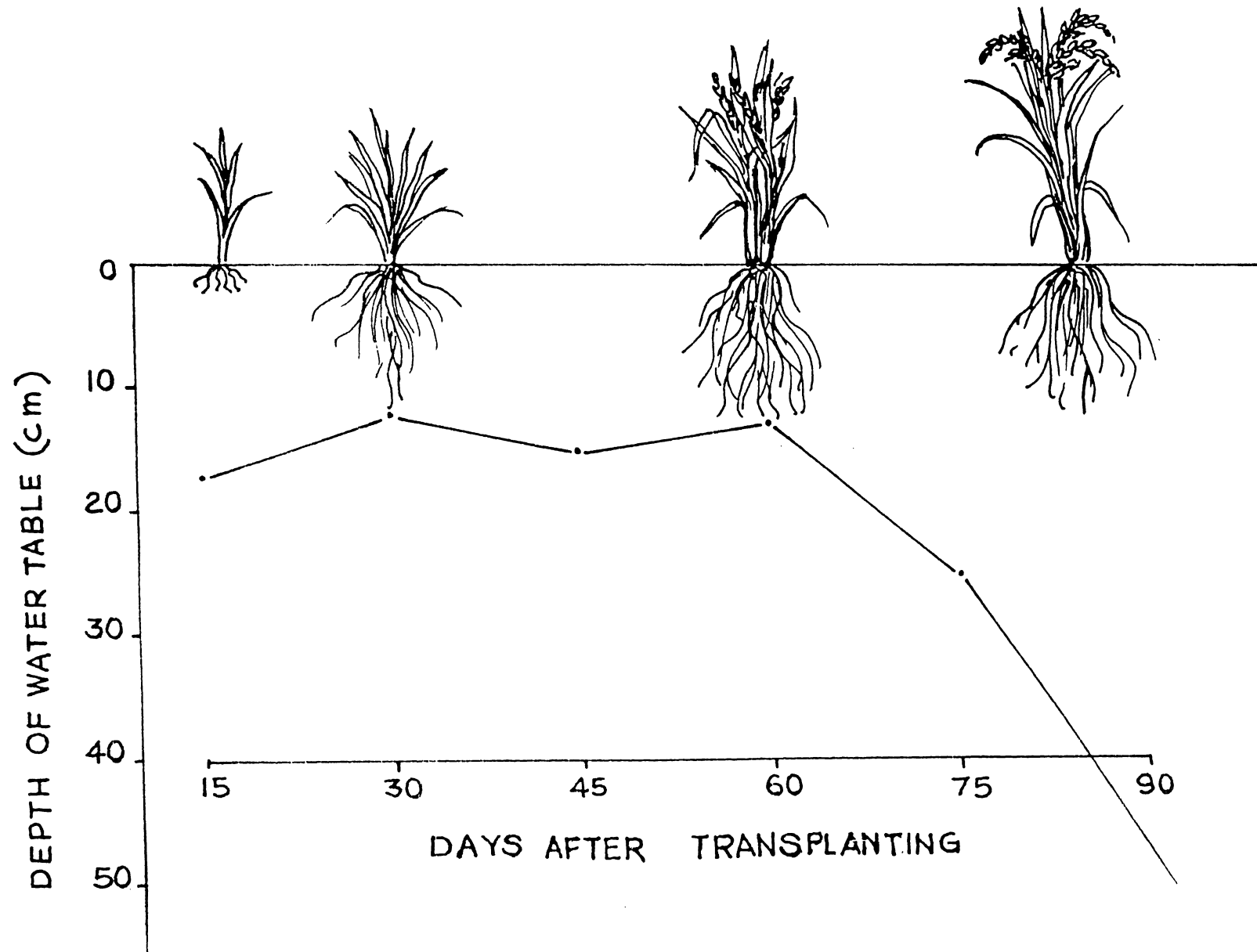
8.1 Treatments

The details of the treatments and the symbols used are presented in Table 4.

TABLE 4. TREATMENTS AND SYMBOLS USED

Treatments	Symbols used
<u>Water Management Schedules</u>	
1. Soil moisture 0 - 0.8 bar	M_1
2. Saturation from TP to PI, rest 3 - 5 cm throughout	M_2
3. Submergence 3 - 5 cm throughout	M_3
4. Five cm irrigation on the day saturation is observed	M_4

Fig. 2. DEPTH OF WATER TABLE DURING GROWING PERIOD



T r e a t m e n t s	Symbols used	
5. Ten cm irrigation on the day saturation is observed	M_5	
6. Ten cm standing water (draining out the standing water, once in a week and reirrigating 10 cm)	M_6	
<u>Nitrogen Management (80 kg N/ha)</u>		
1. No nitrogen (control)	C	(T_1)
2. Urea in 3 splits (50 % basal + 25 % 15 DAT + 25 % at PI)	U_{3s}	(T_2)
3. Urea in 3 splits with soil treatment (50 % basal + 25 % 15 DAT + 25 % at PI)	U_{13s}	(T_3)
4. Urea supergranules incorporated at planting (100 %)	USG 100 % p	(T_4)
5. Urea supergranules at 15 DAT (100 %)	USG 100 % 15 DAT	(T_5)
6. Urea supergranules (50 % at planting + 50 % at 15 DAT)	USG 50 % p + 50 % 15 DAT	(T_6)
7. Urea supergranules (75 % at planting + 25 % N as CAN at PI)	USG 75 % p + 25 % PI	(T_7)
8. Urea (75 % at planting + 25 % N as CAN at PI)	U 75 % p + 25 %PI	(T_8)

8.2 Design and Layout

The experiment with 48 treatments was laid out in a split plot design assigning water management schedules to main plots and nitrogen management treatments to sub-plots each replicated twice. The plan of lay out is presented in Fig. 4. Each main plot was surrounded by a strip of not less than 1 m wide border to prevent plot to plot seepage.

8.3 Plot Size

(a) Gross - 6 m x 3.5 m = 21 sq.m

(b) Net - 5.5 m x 3 m = 16.5 sq.m

9. Nitrogen Fertilizers Used

9.1 Urea: $\text{CO}(\text{NH}_2)_2$

Urea is white, crystalline organic salt, containing about 44 - 46 percent nitrogen (in amide form), an amount greater than that found in any other commercial solid fertilizer. Though not an ammonium fertilizer in the form, it hydrolyses to ammonium carbonate very quickly when added to the soil due to its hygroscopic nature, as shown by the following equation.



Fig. 3.

PLAN OF LAY-OUT



Ammonium carbonate is an unstable compound and decomposes to ammonia and carbon dioxide. The NH_3 or NH_4^+ so released is adsorbed by the colloidal fraction of the soil and subsequently nitrified. Because of the ammonium ion produced by the hydrolysis of this material, it is somewhat acid in its ultimate reaction with the soil.

The hydrolysis of this material is greatly increased in the presence of the enzyme urease, which is found to varying degrees in soils. In most soils it is present in sufficient concentration to bring about the rapid conversion of urea to NH_4^+ . Once in the NH_4^+ form, it behaves like any other ammonical source of nitrogen.

9.2 Urea Supergranule: $\text{CO}(\text{NH}_2)_2$ (USG)

These (modified urea) are large sized granules (1 - 2 g, 11 to 14 mm dia) suitable for its deep placement in wetland rice. The deep point (8 - 10 cm) placement of USG in anaerobic wetland soil creates a placement site with unique chemical and biochemical properties which affect the transformation, movement and uptake of urea-N. The main benefits of USG placement in reduced zone is that nitrogen losses through NH_3 volatilisation, nitrification-denitrification and run off are minimised.

Experiment conducted in our country have shown that there is a high concentration of ammonia at the site of placement. Such high concentration of ammonia is found to be toxic to nitrifiers and the creation of high concentration of ammonia by the placement of USG may act by itself as nitrification inhibitor.

The most important advantage with USG is that this involves placement of nitrogen below soil surface and there it is near perfect placement, which is not possible with ordinary prilled urea particularly in rice fields. The fate of urea supergranule in the rice field illustrated schematically in Fig. 3 and some physical properties of urea and USG presented in Table 5.

TABLE 5. AVERAGE WEIGHT, SURFACE AREA AND SIZE OF UREA AND SUPERGRANULE UREA

Form	Weight (g/particle)	Area cm ² /g	Size (dia) (mm/particle)
1. Prilled urea	0.0035	237	1.6
2. Supergranule urea (Spherical granules)	1.0	41	11.4
3. Supergranule urea (Spherical granules)	2.0	31	14.0

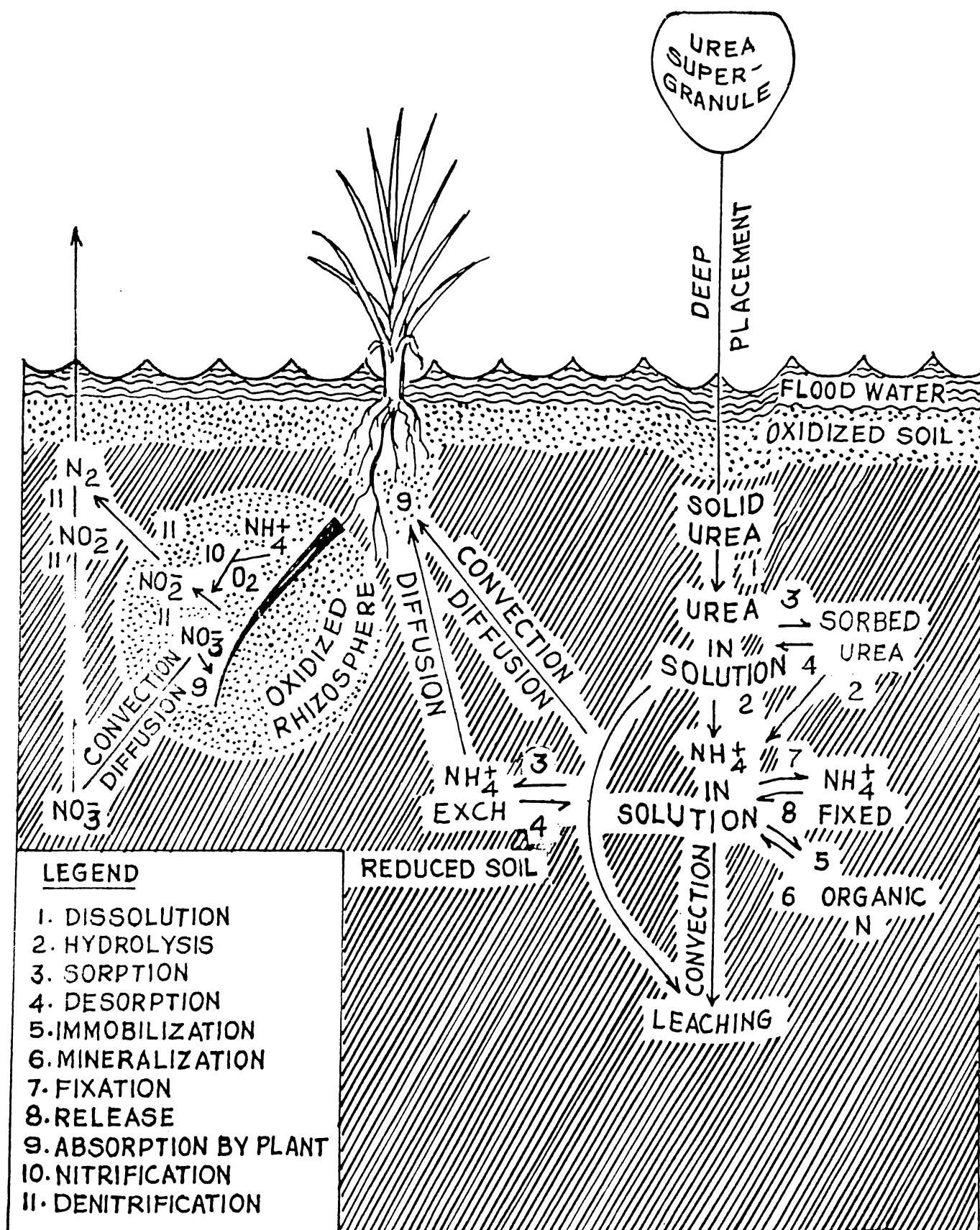


Fig.3(a) SCHEMATIC FATE OF DEEP PLACED UREA SUPERGRANULE IN A WETLAND RICE SOIL

9.3 Soil Treated Urea

The required quantities of urea is incubated with 4 times dry soils and is applied in the field 48 hours after.

9.4 Calcium Ammonium Nitrate (CAN)

CAN is manufactured in an attractive dust free easy flowing granular form containing 25 percent nitrogen. From the total amount of nitrogen present 50 % is in ammonical form and rest 50 % is in nitrate form. It is highly hygroscopic in nature readily available for growing plants and is suitable for use under wide variety of crops and soils.

10. Variety of Rice

Daya (OR 131-13-13, IET 7430)

This variety is evolved by the Orissa University of Agriculture and Technology, Bhubaneswar. It is a short height selection from the cross 'Kumar/CR 57-49', suitable for medium lands and can be grown in Kharif and Rabi seasons; takes about 120 - 125 days to mature, elongates to a height of 70 - 80 cm. This variety has been specifically released for its high level of resistance to gallmidge and brown plant hopper which cause wide spread damage to the rice crop in Kharif and

Rabi seasons, respectively. Hull dull straw coloured; medium slender grains with white kernel (length 5.51 mm, breadth 2.33 L/B ratio 2.87) having thousand grain weight 20 g. The average yield of the variety 4 tonnes with potential for 8 tonnes/hectare.

11. Stages of Growth

The variety 'Days' ripenes in 87 days after transplanting. Variations in date of flowering and ripening as affected by different treatments were recorded from visual observations. The crop growth period was divided into following stages:

1st Stage -	Transplanting to panicle initiation (6.3.83 - 7.4.83)	- 33 days
2nd Stage -	Panicle initiation to flowering (8.4.83 - 4.5.83)	- 27 days
3rd Stage -	Flowering to ripening (5.5.83 - 31.5.83)	- 27 days
		87 days

The crop was harvested on 2.6.83.

12. Measurement of Water

Height of water was maintained by fixing graduated pegs painted black and white. Fall in height of standing water was recorded before each irrigation.

The quantity of water applied to each plot was measured with a 7.5 cm throat Parshall Flume.

13. Calendar of Operation

Details of the calendar of operation are presented in Table 6.

TABLE 6. CALENDAR OF OPERATIONS

Details of operation	D a t e
1. Preparation of nursery bed	30.1.83
2. Sowing of sprouted seeds	1.2.83
3. Preparation of main field	4.3.83
4. Lay out of plots	5.3.83
5. Application of FYM	5.3.83
6. Basal dressing of phosphorus, potash along with nitrogen according to treatment	6.3.83
7. Puddling and transplanting	6.3.83
8. Top-dressing of nitrogen according to management schedule	20.3.83 and 8.4.84
9. Weeding	13.3.83 and 29.3.83
10. Spraying	30.3.83 and 15.4.83
11. Irrigation	According to the water management schedules
12. Harvesting	2.6.83 and 3.6.83
13. Threshing	6.6.83 and 7.6.83

14. Important Cultural Operations

14.1 Transplanting

Final puddling and transplanting was done on 6.3.83. Thirty three days old seedlings were transplanted at a spacing of 15 cm x 10 cm with 2 - 3 seedlings per hill. Seedlings did not grow to appreciable height due to cold. At transplanting the average length of seedling was 9.4 cm (measured up to the auricle of topmost leaf) with 3 - 4 leaves.

14.2 Application of Fertilizer

The rice crop was fertilized at the rate of 80:40:40 kg/ha N, P_2O_5 and K_2O , respectively. In all the treatments phosphorus (single super phosphate) was applied basally but potash (muriate of potash) in two splits i.e., 50 % basal and 50 % with 2nd top-dressing of nitrogen.

Nitrogen fertilizers used were urea, soil treated urea, supergramule urea up CAN. Nitrogen fertilizers were applied according to the treatments in 3 splits (50 % basal (6.3.83), 25 % at 15 DAP (20.3.83) and 25 % at PI stage (8.4.83)).

14.3 Weed Control

Manual weeding done twice to control grasses and sedges. Weed growth in the plots which were kept submerged was very negligible whereas in saturation treatments weed growth was more which required another weeding 50 days after transplanting (24.4.83).

14.4 Plant Protection

Two prophylactic sprays of Dimecron at 0.05 % (5 ml in 10 l water) were given, the first spray 25 days after transplanting and the second 15 days after. Stem borers, rice caseworms and BPH were the major pests observed. While the first two were controlled by spraying the third one was controlled by spreading kerosene in the irrigation water. It did not affect the crop much as the variety is resistant to the pest.

14.5 Harvesting and Threshing

The boarder rows (50 cm) along the length and breadth of the plots were harvested separately. The net plots were harvested on 3.6.83 excluding the sample plants. The sample plants were taken out for recording observations on various yield attributing characters and their yield was added to that of corresponding treatments before subjecting the data to statistical analysis.

The crop was threshed plot-wise separately and the weights were recorded after 3 days sun drying. Final yield was expressed on 14 % moisture basis.

Observations on Growth Characters

1. Sampling Technique

A sample unit having 1 m^2 area was selected at random in each treatment marked by four bamboo pegs at corners and one at middle, for periodical biometric observations as per the technique suggested by Abraham and Mohanty (1955). Biometric observations on height, number of tillers etc. were recorded at 15 days interval from these marked hills commencing from 15th day after planting till ripening.

Observations on leaf area, leaf number and dry matter production were also recorded by taking four hills from the 3rd and 4th row from the East and West side of the boarder rows. Dry matter per clump was recorded after drying the sund dried samples under sun and hot air oven at 80°C for 18 hours. From these data dry matter/ m^2 was calculated.

2. Pre-harvest Observation

(a) Plant height

The height of the main shoot of each hill was measured from the ground level up to the auricle of the topmost leaf till emergence of panicle and upto neck node thereafter.

(b) Tiller number

The total number of tillers from all the clumps of the sample unit were counted per treatment, totalled, averaged and finally computed per m^2 .

(c) Dry matter production

The uprooted sample plants were washed carefully in running water. The samples were first sun dried and then dried in hot air oven at $80^{\circ}C$ to a constant weight.

3. Post-harvest Observations

All the 5 sample hills selected for biometric observation in each sub-plot were harvested together for post-harvest observation.

(a) Number of panicles

At the time of harvest total number of panicles were counted from 5 hills in each plot, averaged out to obtain number of panicles/ m^2 .

(b) Length of panicle

The length of 10 panicles from the five sample plants were measured from the necknode to the tip and averaged out to get the mean length.

- (c) Total number of grains, number of fertile and sterile grains/panicle and fertility percentage

From the sample plants 10 panicles were selected at random and the total number of grains in each panicle was counted separately. The number of fertile and sterile grains in each of these panicles were also counted, totalled and their arithmetic mean was worked out to obtain the mean number of fertile and sterile grains. The fertility percentage was calculated by taking the ratio of the number of fertile grains to total number of grains and multiplying by 100.

- (d) Test weight

One thousand fertile grains were counted from the sampled panicles, their weight was recorded in an electrical balance.

4. Yield Studies

- (a) Yield of grain and straw

Grain and straw yields from net area of all the plots were sun dried for 4 - 5 days were weighed and expressed as q/ha. Similarly the weight of sun dried straw was recorded for each treatment and converted to q/ha by multiplying the hectare factor.

(b) Grain:Straw ratio (g/ha)

It was calculated by dividing the grain yield by the straw yield.

(c) Harvest index

Harvest index was found out by dividing the grain yield of each sub-plot by the total weight of the produce i.e., the biological yield and expressed as percentage.

$$HI = \frac{\text{Grain yield}}{\text{Biological yield (grain + straw)}} \times 100$$

Chemical Analysis(a) Nitrogen

The plant samples collected at the different growth stages were oven dried at 80°C to constant weight, ground and sieved, through 20 mesh sieve and were analysed by modified Kjeldahl method (Jackson, 1957) to determine nitrogen content. The uptake at different stages was computed by multiplying the nitrogen content with the dry matter produced and was expressed as kg/ha.

Statistical Analysis

Data collected on various characters were put to 'F' test appropriate to the experimental design (Cocharan and Cox, 1963). Critical differences only when the 'F' test was found significant, were calculated by multiplying the standard error of mean (S.E.(m)) with 1.414 times and value for 't' at respective error degrees of freedom at 0.05 percent level of significance.

CHAPTER - IV

EXPERIMENTAL FINDINGS

EXPERIMENTAL FINDINGS

During the period of investigation, observations on various plant characters, nutrient uptake, water management practices were recorded to assess the effect of treatments on the growth and yield of rice. The findings are presented in this chapter. The data were statistically analysed where necessary and have been presented in tabular form with the relevant S.E.(m) and C.D. (0.05) values. The tables of the analysis of variance are given in the Appendix.

A. GROWTH AND DEVELOPMENT STUDIES

1. Height of the Plant

Data presented in Table 7 and illustrated graphically in Fig. 4 would show significant influence of various water management practices in increasing the height of rice crop starting from 15 DAT till harvest.

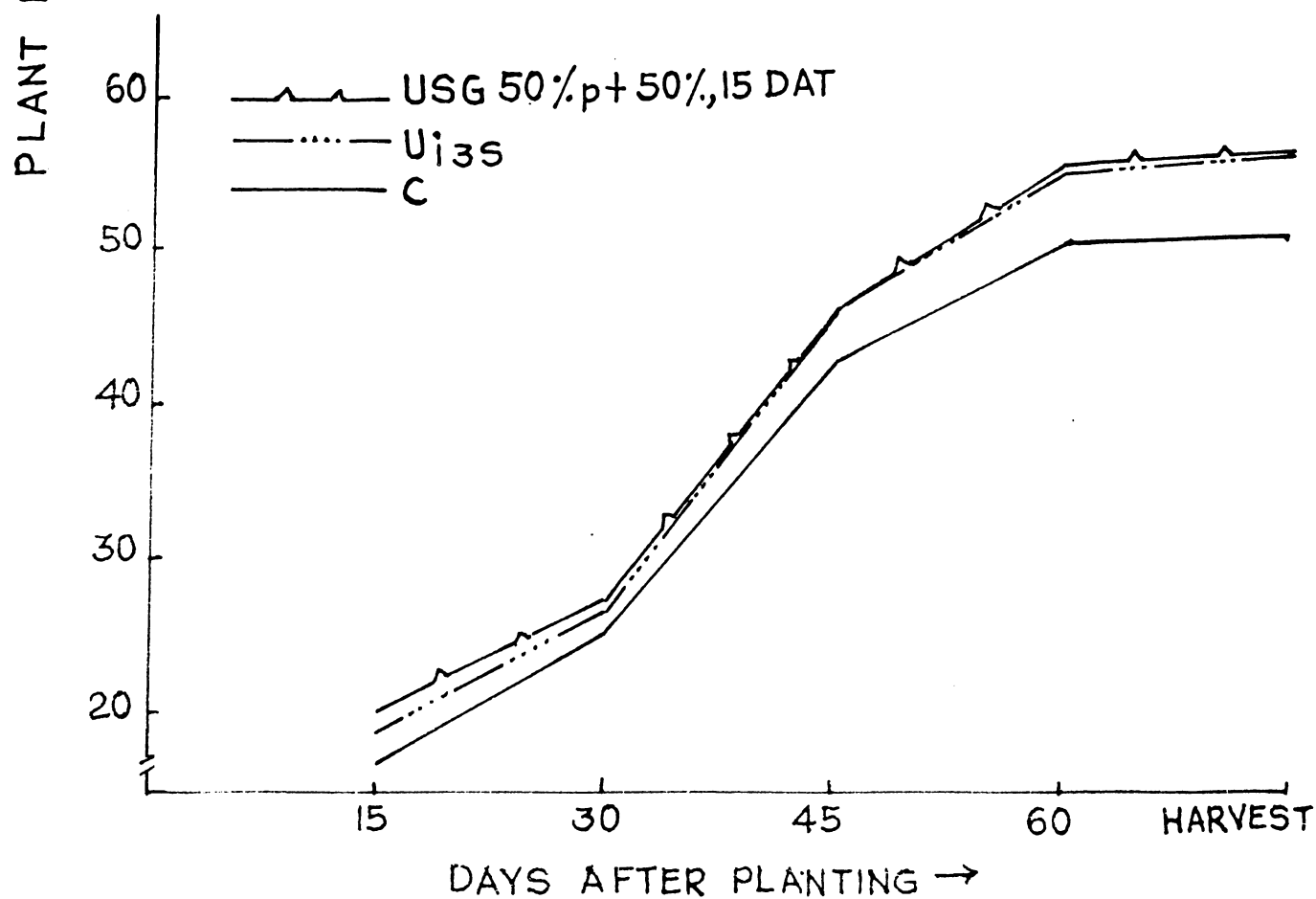
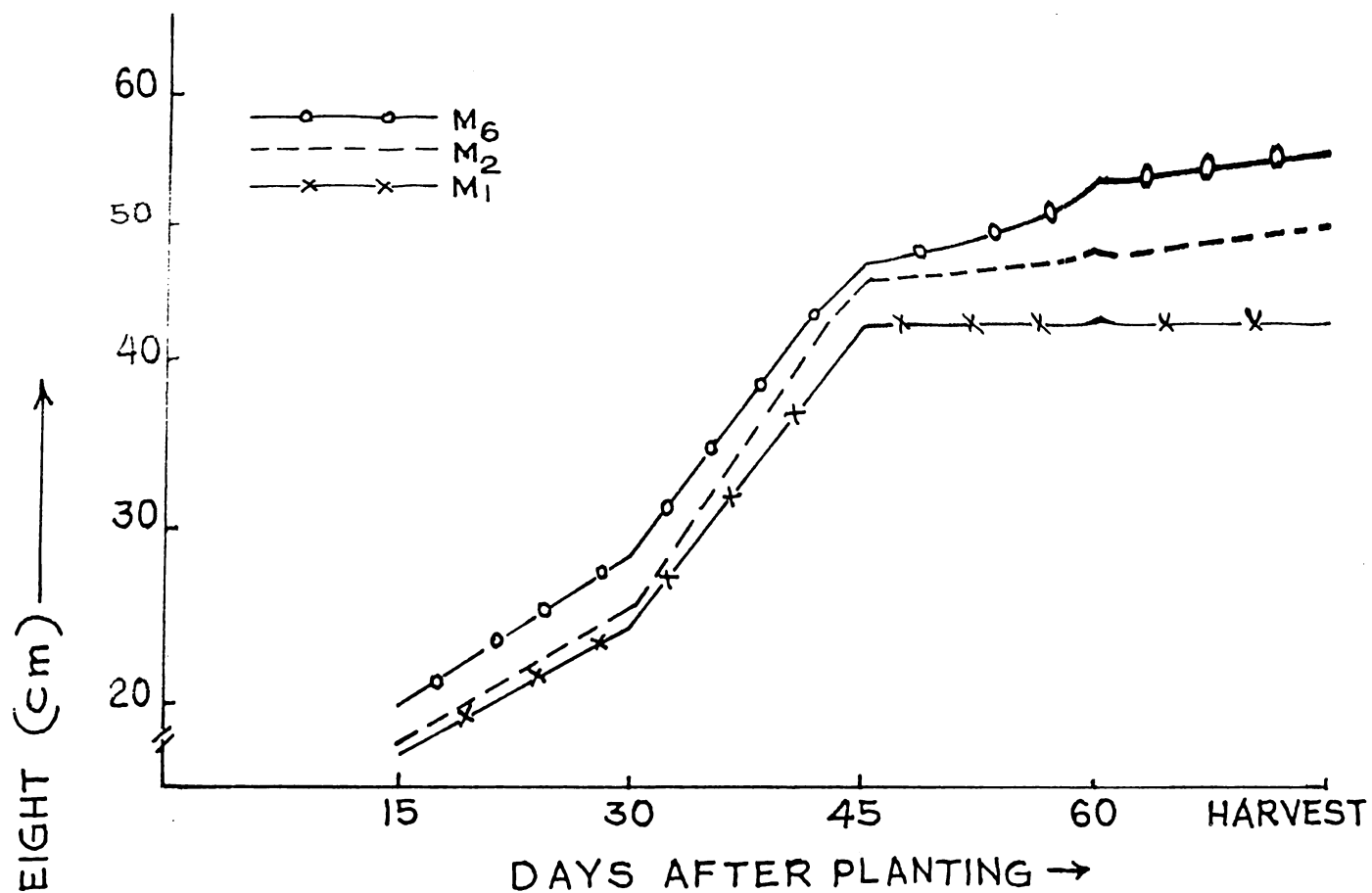
In all the successive period of observations, the treatments M_3 and M_6 i.e., 10 cm irrigation on the day saturation is observed and maintaining 10 cm standing water, draining once in a week, exerted maximum influence on height, closely followed by M_2 i.e., maintaining 3 - 5 cm standing water throughout the growth period,

TABLE 7. EFFECT OF WATER MANAGEMENT PRACTICES, UREA AND SUPER GRANULE UREA ON PLANT HEIGHT (cm) AT DIFFERENT STAGES OF GROWTH

Treatments	Days after planting				
	15	30	45	60	Harvest
Water Management					
M ₁	17.25	24.38	41.75	51.17	51.44
M ₂	17.54	24.93	44.93	53.53	54.74
M ₃	18.21	27.03	46.90	55.43	56.43
M ₄	17.63	25.37	46.03	55.49	56.14
M ₅	19.49	27.68	46.75	55.81	56.62
M ₆	19.77	28.53	46.62	56.05	57.05
S.E. (m) $\pm$	0.18	0.12	0.46	0.38	0.25
C.D. (0.05)	0.65	0.44	1.16	1.38	0.90
Mean	18.31	26.32	45.50	54.58	55.40
Nitrogen Management					
C	16.86	24.92	42.86	50.49	51.06
U _{3m}	18.59	26.27	46.40	54.35	54.91
U _{13m}	18.72	26.54	46.29	55.31	56.28
USG 100 % p	18.63	26.60	45.64	55.61	56.49
USG 100 %, 15 DAT	16.57	26.68	45.56	55.63	56.53
USG 50 % p + 50 %, 15 DAT	20.03	27.13	45.88	55.73	56.65
USG 75 % p + 25 % PI	18.88	26.28	45.13	55.19	55.96
U 75 % p + 25 % PI	18.21	26.21	46.20	54.35	55.35
S.E. (m) $\pm$	0.34	0.33	0.59	0.54	0.54
C.D. (0.05)	0.98	0.94	2.18	1.55	1.55
Mean*	18.52	26.53	45.87	55.17	56.02

* Mean of the nitrogen treatments.

Fig.4.EFFECT OF W_m AND N_m ON PLANT HEIGHT AT DIFFERENT STAGES OF CROP GROWTH.



In the early period of growth, the former two treatments were distinctly superior over the latter; but with the advancement of the growth of the crop, all the above three treatments were found equally effective and significantly increased the height of rice crop over other treatments.

As regards the influence of nitrogen management practices on height, the treatment M_6 (USG 50 % p + 50 % 15 DAT) recorded maximum height of rice plants on 15, 30, 60 DAT and also at harvest. However, its effect was at par with those of the other nitrogen management practices with the advancement of age of the crop. At harvest, excepting control and U_{36} , the rest nitrogen management practices exerted almost similar influence on height ranging from 55.35 cm to 56.65 cm.

Interaction of W_m x N_m

Data presented in Table 7(a) would indicate that there existed significant difference in the interaction of water and nitrogen management with respect to height at 30 DAT. The interaction effect of 10 cm standing water drained once in a week and USG applied at 15 DAT produced the taller plants (30.25 cm).

TABLE 7(a). INTERACTION OF Wm x Nm ON PLANT HEIGHT

Treatments	Interaction at 30 DAT					
	M ₁	M ₂	M ₃	M ₄	M ₅	M ₆
T ₁	21.16	22.96	25.05	26.06	26.79	27.48
T ₂	23.51	23.26	27.23	26.37	28.70	29.56
T ₃	25.69	24.85	27.06	25.60	27.72	28.30
T ₄	25.07	26.93	25.97	25.61	26.26	29.75
T ₅	23.68	25.22	28.77	24.24	27.89	30.25
T ₆	26.47	25.90	28.29	25.93	27.71	28.45
T ₇	25.62	25.41	27.63	24.47	27.37	27.15
T ₈	23.82	24.94	27.24	24.70	28.98	27.57

S.E.(m) for nitrogen in one irrigation = ± 0.811

C.D. (0.05) for N in one irrigation = 2.31

S.E.(m) for irrigation in one nitrogen = ± 0.768

C.D. (0.05) for irrigation in one N = 2.21

2. Number of Tillers/m²

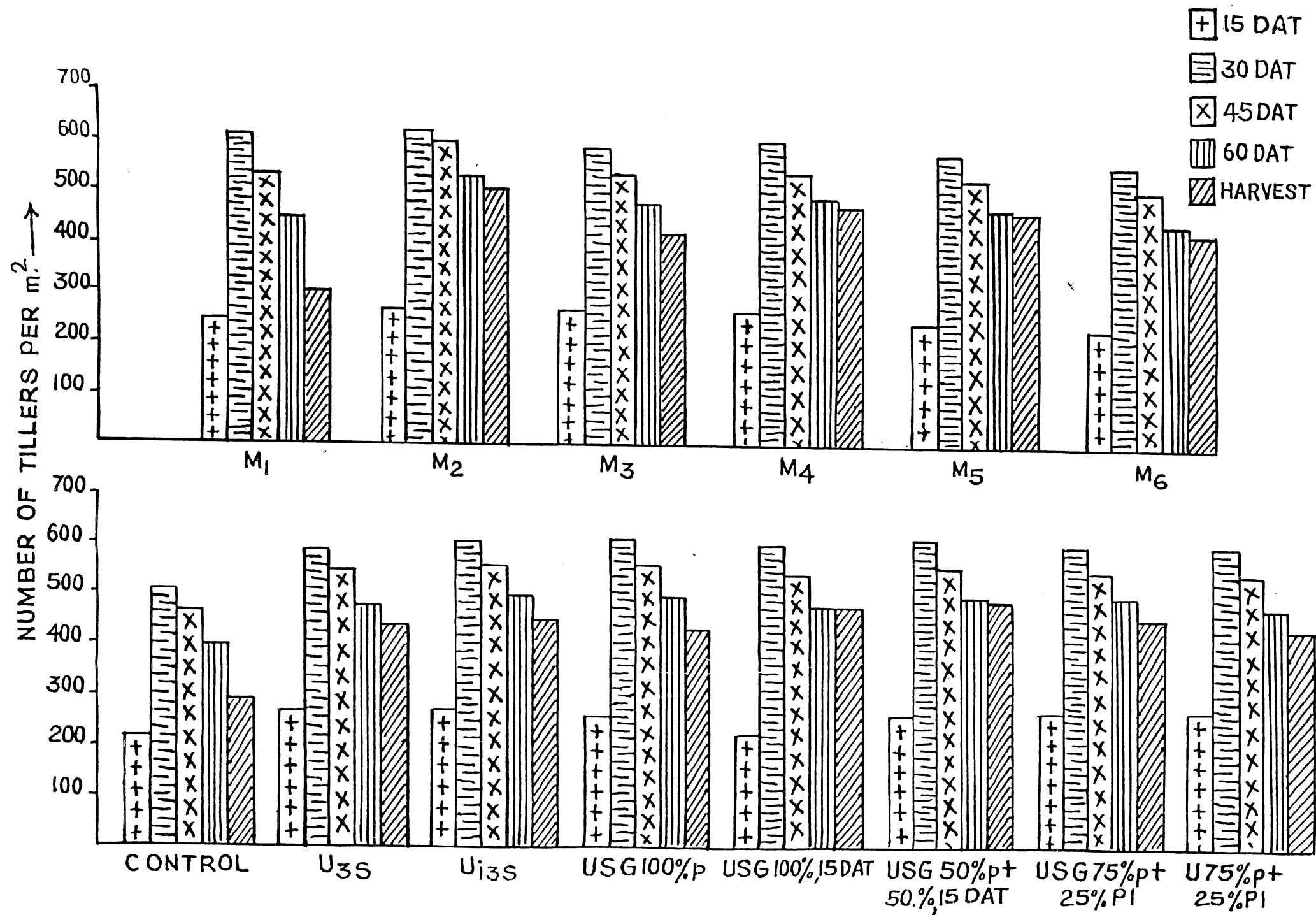
Data presented in Table 8 and illustrated in Fig. 5 indicated significant influence of various water management practices on tiller production during successive growth stages. Among different treatments, M₂ viz., saturation till panicle initiation followed by 3 - 5 cm standing water till ripening recorded maximum number of

TABLE 8. EFFECT OF WATER MANAGEMENT PRACTICES, UREA AND SUPER GRANULE UREA ON TILLERS PER SQUARE METRE AT DIFFERENT STAGES OF GROWTH

Treatments	Days after planting				
	15	30	45	60	Final
<u>Water Management</u>					
M ₁	247.96	607.18	536.25	448.50	313.99
M ₂	270.03	620.50	596.19	532.94	506.02
M ₃	270.65	590.68	540.38	486.81	424.28
M ₄	268.25	604.31	545.87	495.25	480.00
M ₅	250.56	580.25	534.38	476.13	474.03
M ₆	240.19	570.50	515.63	452.19	432.24
S.E. (m) $\pm$	3.62	6.12	11.43	7.31	6.61
C.D. (0.05)	13.17	22.24	41.54	26.57	24.05
Mean	257.94	595.57	544.78	481.97	438.23
<u>Nitrogen Management</u>					
C	219.79	513.42	467.08	404.67	294.50
U _{3s}	272.41	590.75	548.75	480.25	437.94
U _{13s}	270.16	612.92	558.25	498.58	453.36
USG 100 % p	267.20	614.08	565.83	499.75	436.98
USG 100 %, 15 DAT	217.79	605.92	546.33	483.25	482.81
USG 150 % p + 50 %, 15 DAT	267.95	616.08	562.75	502.75	494.81
USG 75 % p + 25 % PI	272.33	605.08	556.00	499.75	459.75
U 75 % p + 25 % PI	275.87	606.33	553.25	486.75	443.25
S.E. (m) $\pm$	5.71	9.54	8.46	7.96	20.01
C.D. (0.05)	16.29	27.23	24.13	22.72	57.12
Mean*	263.39	607.31	622.60	493.01	500.48

* Mean of the nitrogen treatments.

STAGES OF CROP GROWTH



tillers/m² throughout crop growth period till harvest being significant over others on 45, 60 DAT and at harvest.

Regarding nitrogen management practices, the influence of any one treatment on production of tillers was found to be inconsistent. However, the best nitrogen management treatments expressing maximum influence on tillers observed to be USG applied full at 15 DAT followed by USG 50 % at planting and 50 % at 15 DAT.

3. Dry Matter Production

Data presented in Table 9 revealed that among all the treatments M₆ viz., 10 cm standing water draining once in a week significantly produced the highest dry matter of 236.19 g/m² over others as recorded on 30 DAT while on 60 DAT the effect of the above treatment was at par with that of M₅ viz., 10 cm irrigation on the day saturation is observed.

As regards nitrogen management practices, application of USG 50 % as basal and 50 % at 15 DAT in the early stages of growth had produced highest dry matter of 234.92 g/m², being at par with incubated urea applied in 3 splits, USG applied all at planting, USG applied all at 15 DAT and urea 75 % + 25 % N as CAN at panicle initiation. But at 60 DAT, the effect of all the nitrogen management treatments was at par on dry matter production.

TABLE 9. EFFECT OF WATER MANAGEMENT PRACTICES, UREA AND SUPER GRANULE UREA ON DRY MATTER PRODUCTION PER SQUARE METER AT DIFFERENT STAGES OF GROWTH (g)

Treatments	Days after planting	
	30	60
<u>Water Management</u>		
M ₁	194.69	734.43
M ₂	208.87	840.13
M ₃	221.04	834.31
M ₄	218.88	834.13
M ₅	221.75	855.25
M ₆	236.19	847.18
S.E. (m) $\pm$	3.32	6.09
C.D. (0.05)	12.07	22.15
Mean	216.90	824.24
<u>Nitrogen Management</u>		
C	163.25	465.67
U _{3s}	207.33	859.15
U _{13s}	225.13	867.42
USG 100 % p	231.75	880.83
USG 100 %, 15 DAT	229.00	888.33
USG 50 % p + 50 %, 15 DAT	234.92	881.83
USG 75 % p + 25 % PI	215.67	879.67
U 75 % p + 25 % PI	228.17	871.00
S.E. (m) $\pm$	5.55	13.87
C.D. (0.05)	15.83	39.57
Mean*	224.57	875.46

* Mean of the nitrogen treatments.

B. POST-HARVEST STUDIES

1a) Studies on Yield Attributing Characters

1. Number of spikelets/panicle

The average number of spikelets/panicle was 83.26 due to maintenance of soil moisture 0 - 0.8 bar throughout the growth period (Table 10 and Fig. 6). Standing water of 3 - 5 cm throughout (M_3) or after panicle initiation (M_2), irrigation at disappearance of standing water (M_4 and M_5) or 10 cm standing water drained once in a week, increased the number of grains significantly. However, maintaining saturation maximum up to panicle initiation and 3 - 5 cm submergence thereafter till ripening produced the maximum number of grains (109.11) per ear.

Application of 80 kg nitrogen increased the total number of grains to 25.67 per ear than control where no nitrogen was applied (78.58). Application of urea alone or incubated with soil and USG varied the grain numbers significantly. Application of USG 50 % basal and 50 % at 15 DAT resulted in maximum number of (114.13) grains per ear and was found significantly more than that of the application of urea in 3 splits, soil treated urea in 3 splits, USG full as basal, 75 % USG as basal + 25 % CAN at panicle initiation stage and 75 % urea as basal + 25 % CAN at panicle initiation stage.

TABLE 10. EFFECT OF WATER MANAGEMENT PRACTICES, UREA AND SUPER GRANULE UREA ON YIELD ATTRIBUTING CHARACTERS

Treatments	No. of spikelets/panicle	Fertile grains/panicle	% fertility	Length of panicle (cm)	Test weight (g/1000)
<u>Water Management</u>					
M ₁	83.26	50.99	51.55 (61.33)	15.97	18.84
M ₂	109.11	78.59	58.84 (73.08)	16.93	20.71
M ₃	100.71	76.77	60.69 (75.87)	17.36	19.65
M ₄	103.44	75.38	58.44 (72.47)	17.63	20.16
M ₅	106.43	79.17	59.47 (74.05)	17.11	20.51
M ₆	105.78	75.15	57.43 (70.82)	17.63	19.44
S.E. (m) $\pm$	8.80	1.81	0.87	0.31	0.16
C.D. (0.05)	6.56	6.59	3.18	-	0.60
Mean	101.46	72.68	57.74 (71.27)	17.11	19.89
<u>Nitrogen Management</u>					
C	78.58	49.03	52.21 (62.42)	15.96	18.65
U _{3s}	93.31	65.94	57.34 (70.61)	17.06	19.68
U _{13s}	105.80	76.02	57.89 (71.68)	17.27	20.02
USG 100 % p	107.16	76.23	57.34 (70.68)	17.78	19.93
USG 100 % 15 DAT	109.40	81.92	59.75 (74.43)	16.89	20.27
USG 50 % p + 50 % 15 DAT	114.13	86.27	60.17 (75.00)	17.18	20.59
USG 75% p + 25 % PI	100.85	74.10	58.94 (73.22)	17.17	20.59
U 75 % p + 25 % PI	99.08	71.89	58.24 (72.11)	17.54	19.50
S.E. (m) $\pm$	1.87	1.65	0.68	0.23	0.19
C.D. (0.05)	5.35	4.71	1.95	0.66	0.54
Mean*	104.25	76.05	58.52 (72.53)	17.27	20.08

Figures in parentheses indicate original fertile grains %.

Interaction of Wm x Nm

The interaction effect of water management and nitrogen management were statistically found significant (Table 10(a)).

TABLE 10(a). INTERACTION OF Wm x Nm ON NUMBER OF SPIKELETS

Treatments	Interaction on number of spikelets					
	M ₁	M ₂	M ₃	M ₄	M ₅	M ₆
T ₁	74.65	76.45	79.00	82.15	78.85	80.35
T ₂	85.65	96.90	94.10	93.65	88.95	100.60
T ₃	86.70	111.45	97.20	107.60	112.25	119.60
T ₄	81.31	108.70	106.10	102.65	119.85	124.35
T ₅	87.65	115.20	114.00	114.05	114.05	111.45
T ₆	91.05	128.10	116.75	123.85	115.20	109.85
T ₇	81.45	108.85	100.45	99.85	114.15	100.35
T ₈	77.60	107.20	98.10	103.70	108.15	99.70

S.E.(m) for nitrogen in one irrigation = ± 4.590

C.D. (0.05) for N in one irrigation = 13.10

S.E.(m) for irrigation in one nitrogen = ± 4.657

C.D.(0.05) for irrigation in one N = 13.83

Irrespective of water management schedules the grain numbers per panicle increased due to application of 80 kg nitrogen/hectare. The number was least (74)

under soil moisture 0 - 0.8 bar and increased up to a maximum of 128 due to irrigation at different schedules. Application of 50 % USG as basal and 50 % at 15 DAT in the water management schedule of saturation till panicle initiation followed by 3 - 5 cm submergence till ripening resulted in maximum grain numbers per panicle (128), from the treatments of irrigation either 5 cm or 10 cm depth on days of observance of saturation.

2. Number of Fertile Grains/panicle

The data presented in Table 10 and illustrated in Fig. 6 revealed that where soil moisture 0 - 0.8 bar maintained throughout, produced the least number of fertile grains (50.99) being significantly less than other water management schedules. The rest of the treatments were at par as regards water management schedules, however 10 cm irrigation on the day saturation is observed produced the maximum number of fertile grains (79.17) per panicle.

In the control treatment where no nitrogen was applied the number of fertile grains were the least (49.03) and increased significantly in other treatments on an average of 27.02 number of fertile grains/panicle where 80 kg nitrogen was applied. Again the treatment

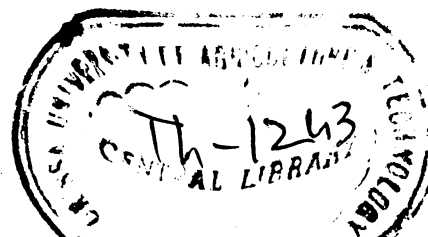
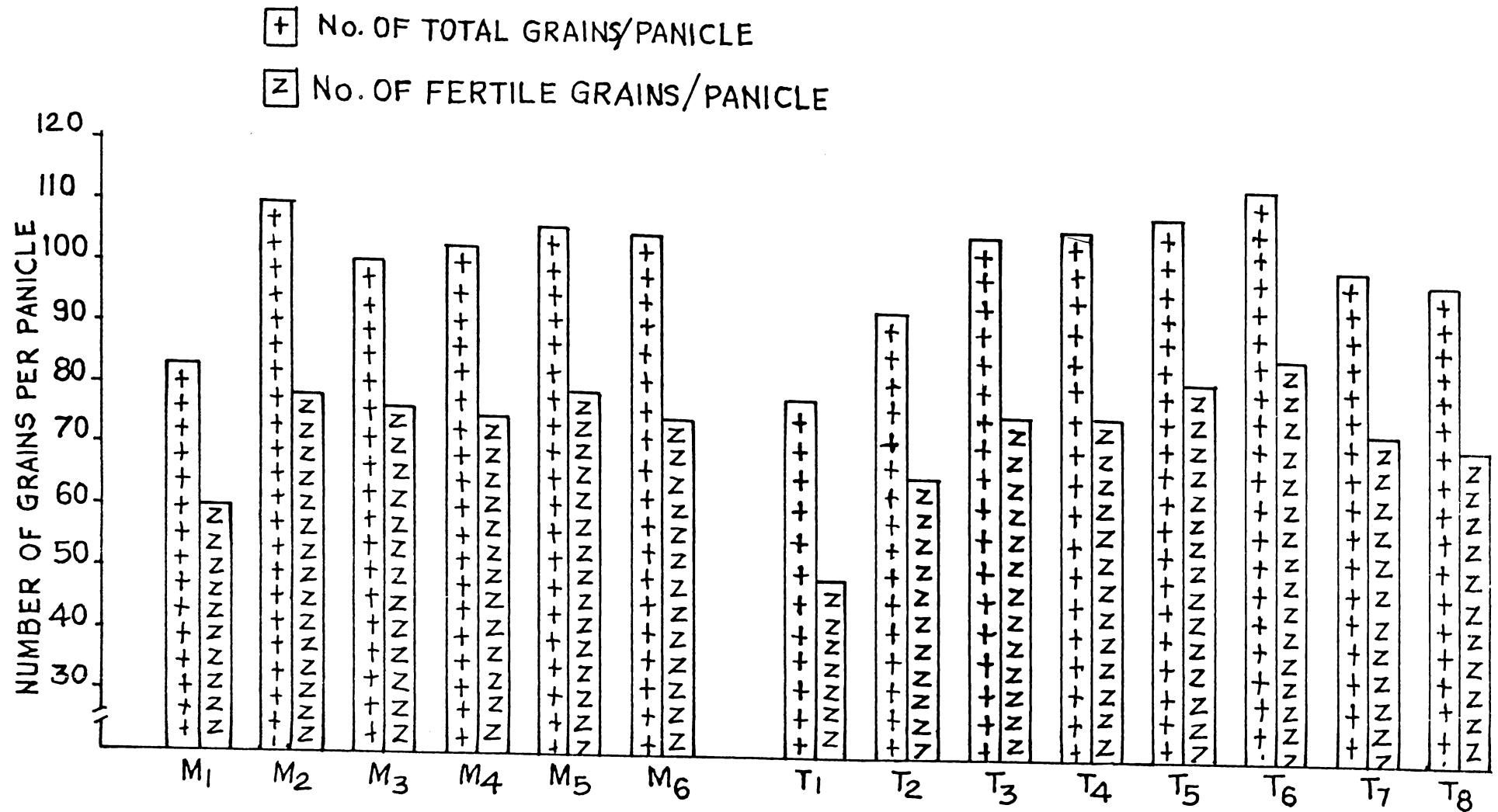


Fig.6. EFFECT OF W_m AND N_m ON TOTAL NUMBER OF GRAINS AND NUMBER OF FERTILE GRAINS / PANICLE



where urea was applied in 3 splits, differ significantly from other treatments producing 65.94 fertile grains only. However, the treatment where 50 % USG as basal and 50 % at 15 DAT produced maximum number of fertile grains (86.27) which was significantly higher as compared to the other treatments. The rest of the treatments were at par.

Interaction of Wm x Nm

Data presented in Table 10(b) would indicate that there existed significant difference in the interaction of water and nitrogen management with respect to this character. The interaction effect of saturation up to panicle initiation and 3 - 5 cm submergence till ripening combined with USG applied 50 % basal and 50 % at 15 DAT produced the maximum number of fertile grains (102.70). However, other irrigation schedules like 3 - 5 cm submergence throughout and 5 cm or 10 cm irrigation on the day saturation is observed did not vary significantly with this fertilizer dose in producing fertile grains.

3. Fertility Percentage

Water management schedules influenced fertility of grains favourably and in the present investigation it was found to increase significantly in the treatments where submergence followed at the time of grain filling

TABLE 10(b). INTERACTION OF Wm x Nm ON NUMBER OF FERTILE GRAINS PER PANICLE

Treatments	Interaction on fertile grains/panicle					
	M ₁	M ₂	M ₃	M ₄	M ₅	M ₆
T ₁	44.10	47.50	52.50	50.75	50.60	48.75
T ₂	50.30	70.60	69.55	68.25	67.55	69.40
T ₃	53.70	83.10	73.80	78.40	83.85	83.25
T ₄	48.80	82.15	79.10	73.90	90.60	82.80
T ₅	55.80	89.40	89.45	85.00	90.60	81.25
T ₆	55.60	102.70	93.10	93.05	87.65	85.50
T ₇	52.30	76.95	83.35	72.55	84.65	74.88
T ₈	47.35	76.30	73.30	81.10	77.85	75.45

S.E.(m) for nitrogen in one irrigation = ± 4.043

C.D. (0.05) for N in one irrigation = 11.55

S.E.(m) for irrigation in one nitrogen = ± 4.194

C.D. (0.05) for irrigation in one N = 12.57

but decreased in the soil moisture of 0 - 0.8 bar treatment (M₁). The highest fertility percentage was found in the treatment (M₂) where 3 - 5 cm submergence followed throughout (75.87%) and lowest (61.33 %) in the M₁ treatment.

In the nitrogen management practices the form and time of application of urea fertilizers play greater

role in influencing the fertility percentage of grains. Application of urea in three splits, incubated urea and USG at planting differed significantly from the treatment where USG applied in 2 splits i.e., 50 % at planting and 50 % at 15 DAT (75.00 %), which was at par with USG applied all at 15 DAT, USG 75 % at planting and 25 % N as CAN at panicle initiation and urea 75 % at planting, rest as CAN at panicle initiation stage. In the treatment where no nitrogen was applied the percentage fertile grains was only 62.42 %.

4. Length of Panicle

Data presented in Table 10 and illustrated in Fig. 7(a) indicated that there was no effect of water management schedules on the length of panicle. However, 5 cm irrigation on the day saturation is observed and 10 cm standing water drained once in a week showed equal and maximum panicle length of 17.63 cm which was 9.41 % more than soil moisture 0 - 0.8 bar.

In the nitrogen management practices least panicle length of 15.96 cm was observed in the control treatment where no nitrogen was applied and it differed significantly from others. There was no significant difference among other treatments except in the treatment of 80 kg nitrogen as USG applied basally which recorded the maximum panicle length of 17.78 cm.

Fig.7.a. EFFECT OF $W_m \times N_m$ ON PANICLE LENGTH (cm)

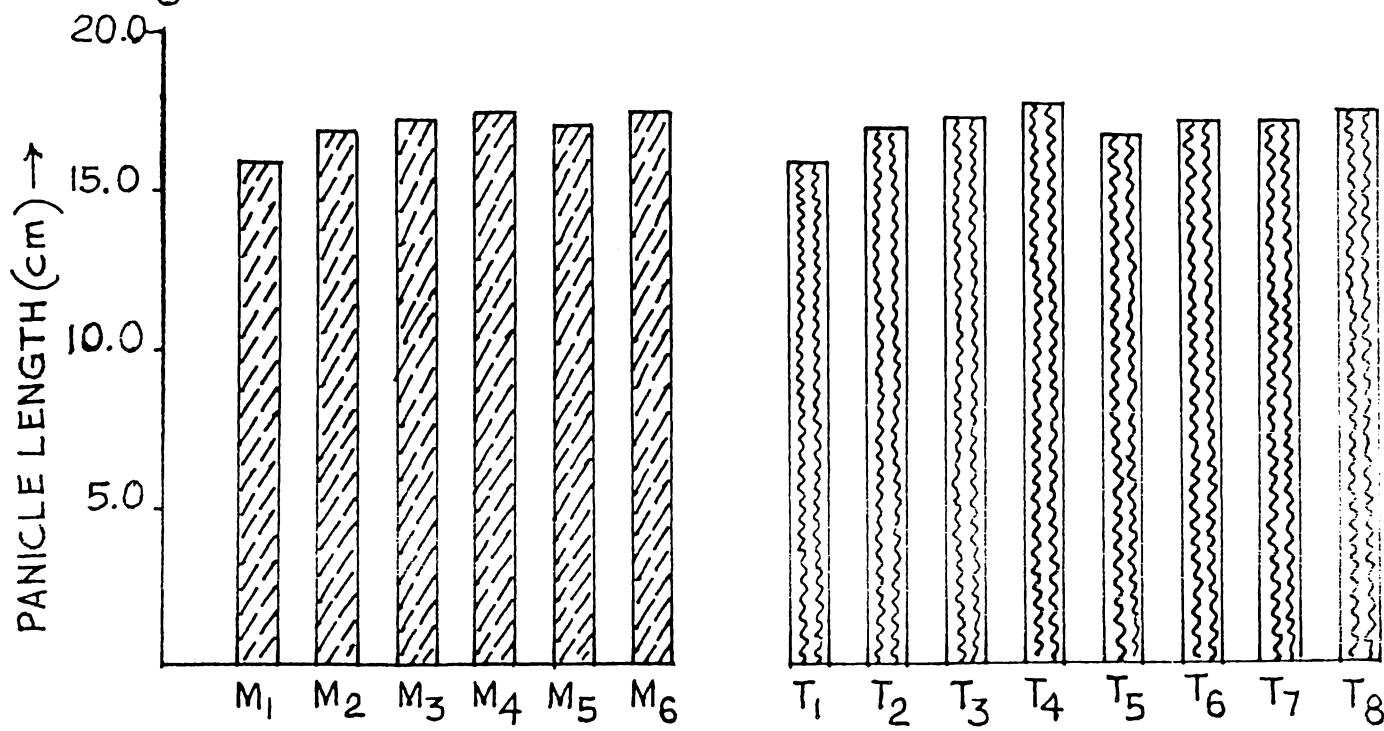
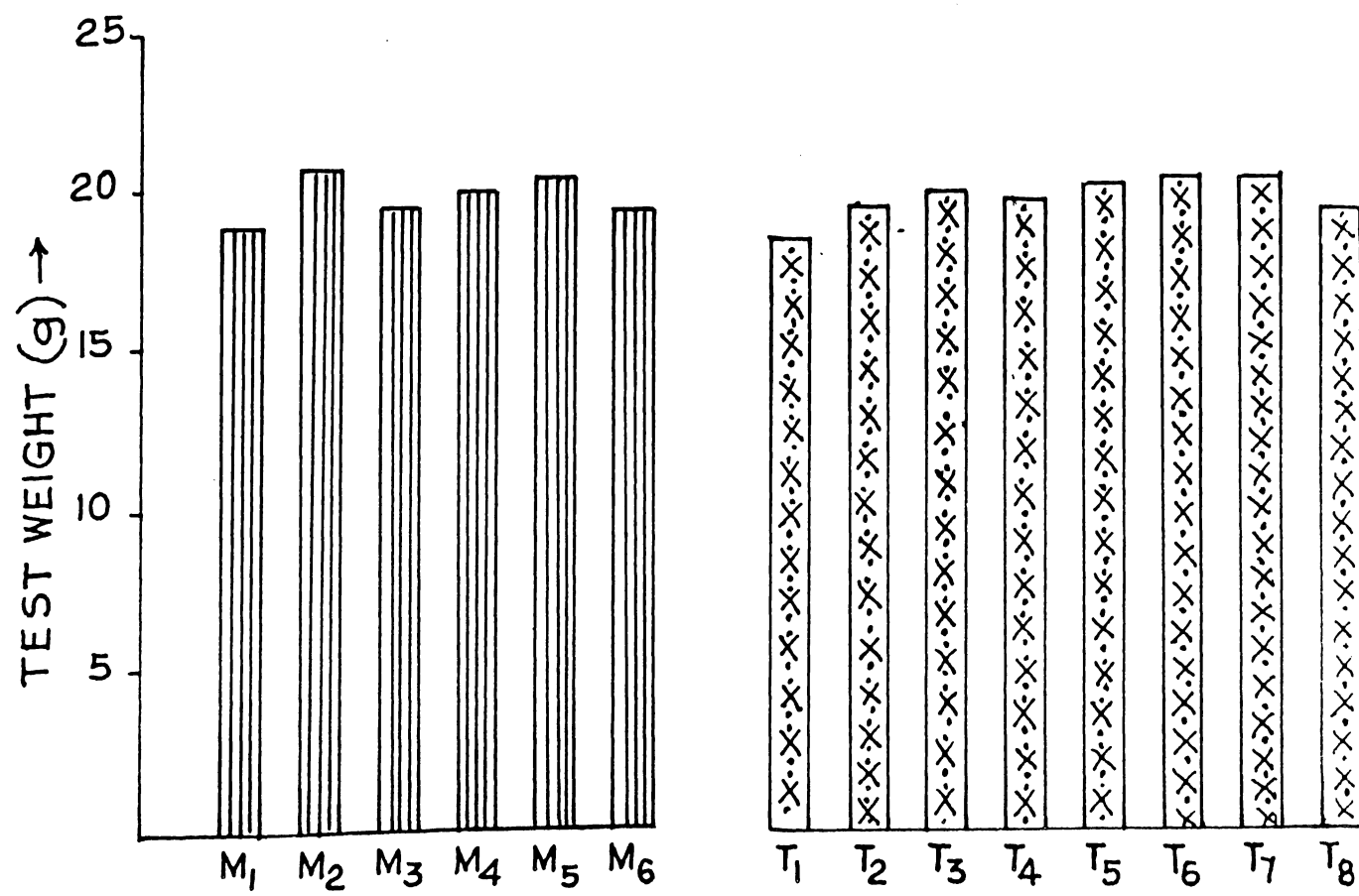


Fig.7.b. EFFECT OF $W_m \times N_m$ ON 1000 GRAIN WEIGHT (g)



5. Test Weight

Data presented in Table 10 and depicted in Fig. 7(b) indicated that there was significant variation in test weight due to different water management schedules. The test weight was the least (18.84 g) with soil moisture 0 - 0.8 bar and increased significantly due to standing water either throughout or after panicle initiation. The maximum test weight of 20.71 g was obtained through maintenance of moisture at about saturation till panicle initiation followed by 3 - 5 cm standing water till ripening.

The test weight under control was only 18.65 g and increased significantly by about 1.43 g due to application of 80 kg nitrogen. Application of 50 % nitrogen as basal and 50 % at 15 DAT in the form of USG or 75 % nitrogen as USG applied basal and 25 % through CAN at panicle initiation stage produced maximum test weight of 20.59 g.

(b) Grain Yield

Data presented in Table 11 and illustrated in Fig. 8 would indicate that there existed significant variation in the yield due to water management practices. The yield of grains was the least (28.49 q/ha) with soil

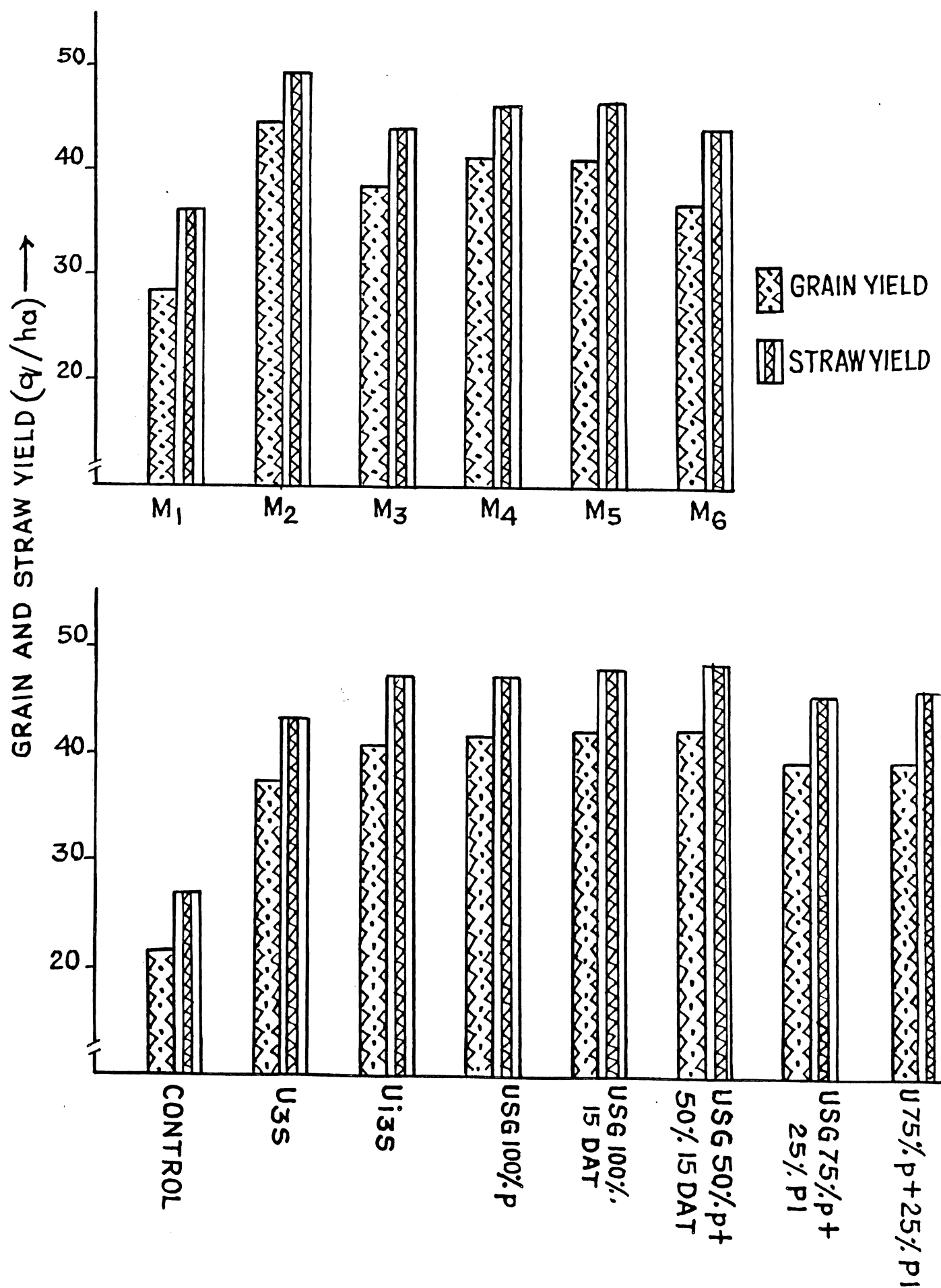
TABLE 11. EFFECT OF WATER MANAGEMENT PRACTICES, UREA AND SUPER GRANULE UREA ON YIELD OF GRAIN, STRAW, GRAIN:STRAW RATIO AND HARVEST INDEX

Treatments	Grain yield (q/ha)	Straw yield (q/ha)	Grain/Straw ratio	Harvest index (%)
<u>Water Management</u>				
M ₁	28.49	36.09	0.790	41.61 (44.10)
M ₂	44.39	49.39	0.893	43.51 (47.40)
M ₃	38.65	43.98	0.878	43.08 (46.16)
M ₄	40.98	45.82	0.892	43.35 (47.11)
M ₅	40.19	46.27	0.868	42.94 (46.37)
M ₆	36.53	43.78	0.837	42.42 (45.50)
S.E. (m) $\pm$	1.79	1.50	0.012	0.21
C.D. (0.05)	6.48	5.45	0.044	0.76
Mean	38.205	44.22	0.860	42.82 (46.11)
<u>Nitrogen Management</u>				
C	21.43	26.96	0.799	41.77 (44.37)
U _{3a}	37.30	43.24	0.858	42.84 (46.21)
U _{13a}	40.85	47.39	0.864	42.86 (46.27)
USG 100 % p	41.90	47.76	0.874	43.20 (46.88)
USG 100 %, 15 DAT	42.24	48.15	0.878	43.08 (46.66)
USG 50 % p + 50 %, 15 DAT	42.56	48.45	0.879	43.07 (46.63)
USG 75 % p + 25 % PI	39.79	45.77	0.866	42.90 (46.34)
U 75 % p + 25 % PI	39.56	46.06	0.861	42.82 (45.51)
S.E. (m) $\pm$	1.68	2.07	0.019	0.34
C.D. (0.05)	4.79	5.94	-	-
Mean*	40.60	46.69	0.869	42.97 (46.36)

* Mean of the nitrogen treatments.

Figures in parentheses indicate original harvest index.

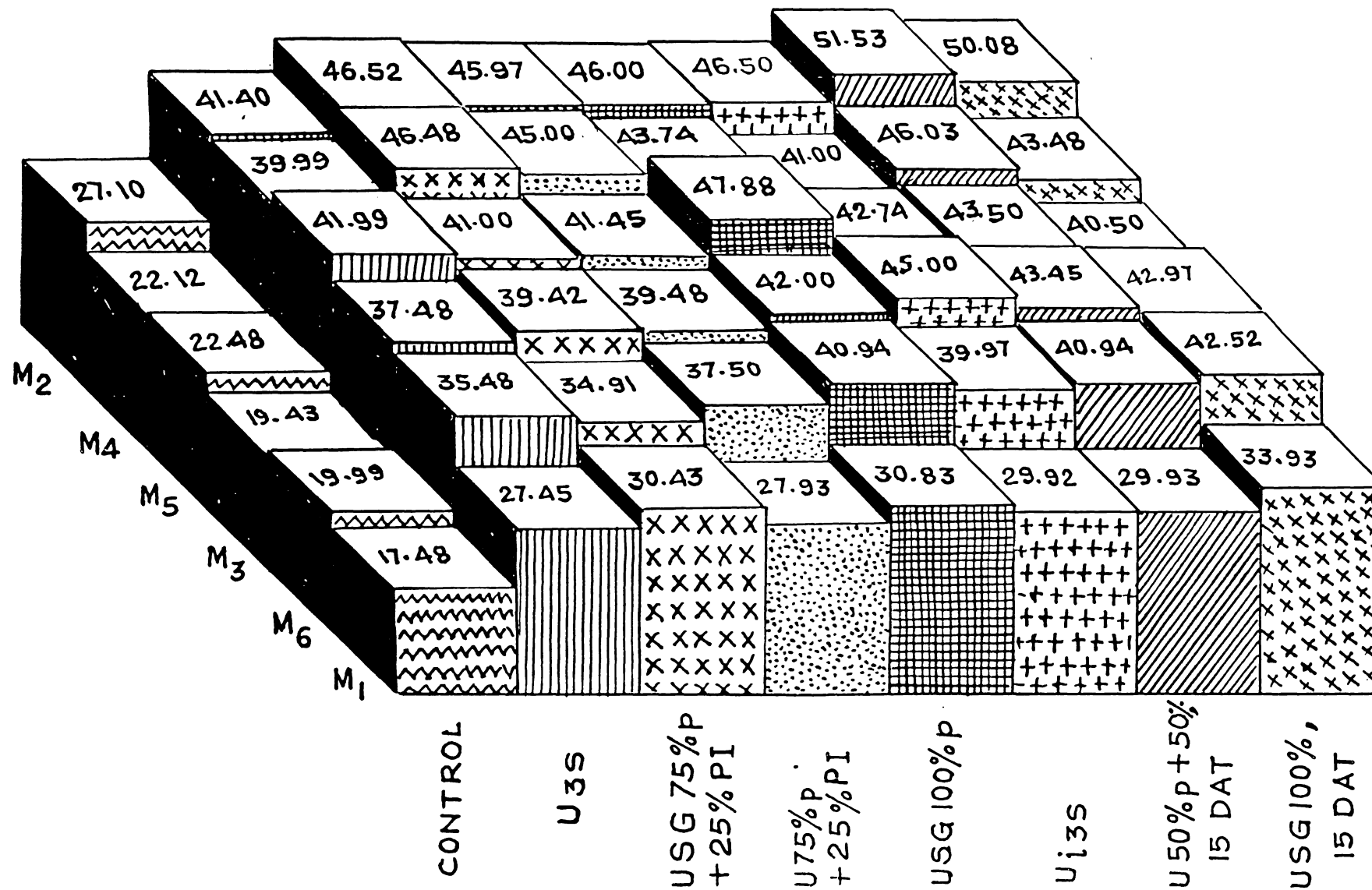
Fig.8. EFFECT OF W_m AND N_m ON GRAIN & STRAW YIELD (q_t/ha)



moisture 0 - 0.8 bar and increased significantly due to presence of standing water either throughout or after panicle initiation. The maximum yield of 44.4 q/ha was obtained due to maintenance of moisture at about saturation till panicle initiation followed by 3 - 5 cm standing water till ripening. Maintenance of 10 cm standing water throughout increase yield only by 8 q/ha was found much inferior to saturation till panicle initiation followed by 3 - 5 cm standing water till ripening. Other water management schedules did not have significant effect on grain yield, though their yields were significantly more than due to continuous saturation.

The yield under control (No nitrogen) was only 21.4 q/ha and increased significantly by about 19.2 quintals due to application of 80 kg nitrogen. When applied in form of urea alone the yield increased by 16 q/ha. Application of soil treated urea increased the yield by 3 q further (40.8 q/ha). Application of 80 kg nitrogen as USG whether applied all as basal, 15 days after planting or 50 % as basal and 50 % at 15 DAT produced equal results and the yield was about 42 q/ha which was only 4.9 quintals more than application of the same quantity of nitrogen applied in 3 splits as urea. The difference in yield due to application of soil treated urea and different combination of USG did not vary significantly.

Fig.8a.EFFECT OF INTERACTION OF $W_m \times N_m$ ON GRAIN YIELD (q/ha)



(c) Straw Yield

Data presented in Table 11 and illustrated in Fig. 8 indicated that there was significant variation in straw yield due to water management schedules. The yield of straw was the least (36.09 q) with soil moisture 0 - 0.8 bar and increased significantly due to standing water either throughout or after panicle initiation. The maximum yield of 49.39 q/ha was obtained due to maintenance of moisture at about saturation till panicle initiation followed by 3 - 5 cm standing water throughout increased the straw yield only by 7 q/ha was found much inferior to saturation till panicle initiation followed by 3 - 5 cm standing water till ripening. Other water management schedules did not have significant effect on straw yield, though their yields were significantly more than that due to soil moisture 0 - 0.8 bar.

The straw yield under control (No nitrogen) was only 26.9 q/ha and increased significantly by about 19 quintals due to application of 80 kg nitrogen. When applied in form of urea alone the yield increased by 17 q/ha. Application of soil treated urea increased the yield by 4 quintals further (47.39 q/ha). Application of 80 kg nitrogen as USG whether applied all as basal

15 DAT or 50 % as basal and 50 % at 15 DAT stproduced equal results and the straw yield was about 48 q/ha which was 5 quintals more than the application of same quantity of nitrogen as urea applied in 3 splits i.e., 50 % basal, 25 % at 15 DAT and 25 % at panicle initiation stage. The difference in straw yield due to application of soil treated urea (applied in splits like urea) and different combination of USG did not vary significantly.

(d) Grain:Straw Ratio

The grain:straw ratio due to influence of different water and nitrogen management practices was found out. The data are presented in Table 11 and depicted in Fig. 9(a).

The grain:straw ratio influenced by water management practices vary significantly. The average being 0.860 and the highest 0.893 found in the treatment (M_2) where submergence followed after panicle initiation. This treatment was at par with all the submergence treatments except the treatment where water was drained out each week. In the treatment where soil moisture maintained at 0 - 0.8 bar the grain:straw ratio found to be only 0.790.

Fig.9a. EFFECT OF W_m AND N_m ON GRAIN /STRAW RATIO

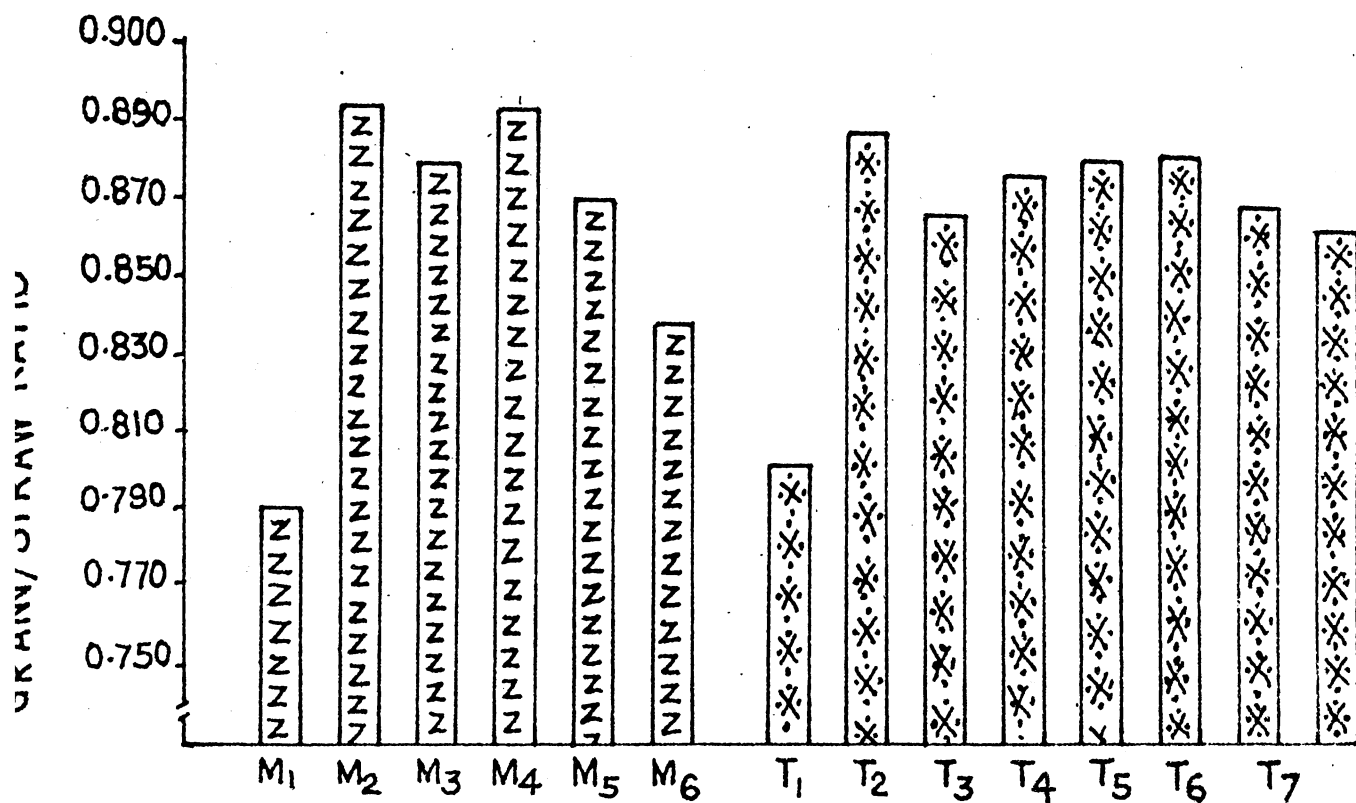
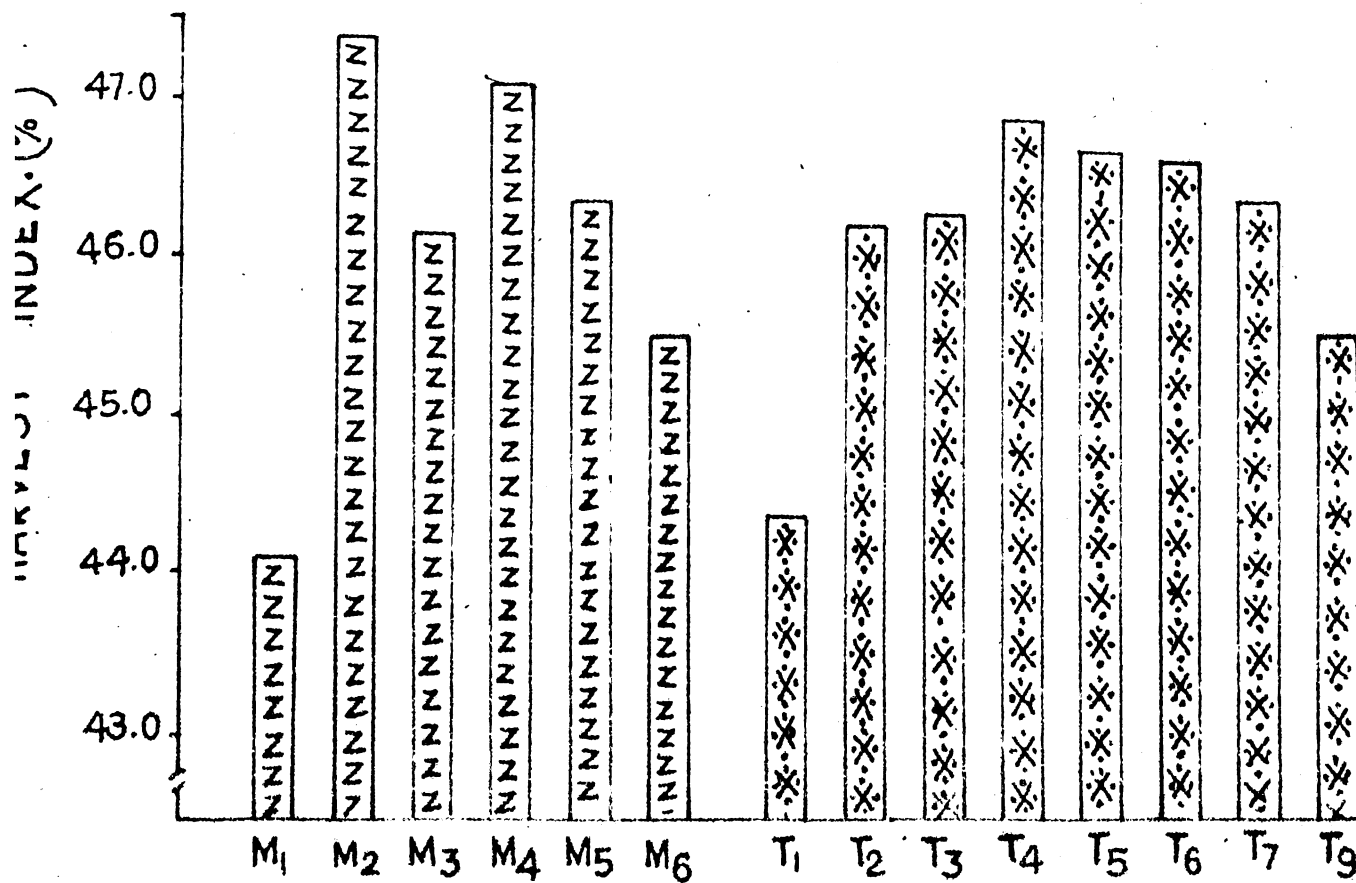


Fig.9b. EFFECT OF W_m AND N_m ON HARVEST INDEX



Statistically nitrogen management practices did not influence grain:straw ratio. But the highest value (0.879) found in the treatment (T_6) where USG applied in 2 splits at an interval of 15 days, the average being 0.869.

(e) Harvest Index

Data on harvest index (H.I) as influenced by different treatments are presented in Table 11 and illustrated in Fig. 9(b).

The different water management schedules significantly affected the harvest index of the crop. The M_2 treatment (saturation up to panicle initiation + 3 - 5 cm submergence thereafter) gave the highest harvest index (47.40 %) and the lowest being the M_1 (soil moisture 0 to 0.8 bar) i.e., only 44.10 %.

The nitrogen management practices had no influence on harvest index. The average harvest index observed 46.36 % and lowest in control where no nitrogen was applied (44.37 %).

C. NUTRIENT STUDIES

1. Nitrogen Content

Data on nitrogen content at different stages of crop growth (30 DAT and 60 DAT) and at harvest in

both grain and straw, are presented in Table 12. The data were not statistically analysed and mean values as determined from the composite samples were given.

The nitrogen content in plants was found to be more in earlier stages and decreased gradually as observed both in water and nitrogen management practices in most of the treatments. The nitrogen content in grain (1.146 %) and straw (0.488 %) was found to be more in M_2 , where saturation followed till panicle initiation and 3 - 5 cm submergence thereafter. In the nitrogen management schedule incubated urea treatment, containing 1.152 % nitrogen was found superior followed by USG applied 50 % as basal and 50 % at 15 DAT.

2. Uptake of Nitrogen

The nitrogen uptake (Table 13 and Fig. 10(a)) by both grain and straw was found more in the treatment where saturation was maintained till panicle initiation followed by 3 - 5 cm standing water, (48.94 kg grain and 23.64 kg straw). The super granule urea treatments were found superior to others but at par with incubated urea in this respect.

3. Recovery of Nitrogen

The recovery of nitrogen both from soil and fertilizer are presented in Table 13 and depicted in

TABLE 12. EFFECT OF WATER MANAGEMENT PRACTICES, UREA AND SUPER GRANULE UREA ON NITROGEN CONTENT (%) IN PLANT, GRAIN AND STRAW AT SUCCESSIVE STAGES OF GROWTH

Particulars	Days after planting		Harvest	
	30	60	Grain	Straw
<u>Water Management</u>				
M ₁	2.069	1.689	1.123	0.407
M ₂	2.045	2.192	1.146	0.488
M ₃	2.138	1.955	1.139	0.453
M ₄	2.233	2.189	1.129	0.423
M ₅	1.195	1.804	1.139	0.424
M ₆	2.020	1.966	1.108	0.406
Mean	1.950	1.966	1.131	0.434
<u>Nitrogen Management</u>				
C	1.697	1.384	1.048	0.381
U _{3s}	2.053	1.929	1.141	0.428
U _{13s}	2.246	2.085	1.152	0.436
USG 100 % p	2.182	1.871	1.144	0.403
USG 100 %, 15 DAT	2.688	2.605	1.146	0.464
USG 50 % p + 50 %, 15 DAT	2.666	2.221	1.150	0.488
USG 75 % p + 25 % PI	2.160	2.027	1.139	0.446
U 75 % p + 25 % PI	2.220	2.027	1.129	0.420
Mean*	2.316	2.121	1.143	0.441

* Mean of the 7 treatments excluding control.

TABLE 13. EFFECT OF WATER MANAGEMENT PRACTICES, UREA AND SUPER GRANULE UREA ON NITROGEN UPTAKE BY GRAIN AND STRAW (kg/ha) AND THEIR NITROGEN USE EFFICIENCY

Particulars	Yield (g/ha)		Nitrogen uptake in (kg/ha)			Recovery of applied N over control (%)	Utilisation from fertilizer (%)	Protein content	Yield increased over control (%)		Nitrogen use efficiency	
	Grain	Straw	Grain	Straw	Total				Grain	Straw	kg grain/kg N	kg straw/kg N
C	21.43	26.96	22.45	10.27	32.72	-	-	6.55	-	-	-	-
U _{3a}	37.30	43.24	42.56	18.51	61.06	46.42	35.43	7.13	42.55	37.65	19.84	20.35
U _{13a}	40.85	47.39	47.06	20.66	67.72	51.68	43.75	7.20	47.54	43.11	24.28	25.53
USG 100 % p	41.90	47.76	47.93	19.25	67.18	51.29	43.08	7.15	48.85	43.55	25.59	26.25
USG 100 %, 15 DAT	42.24	48.15	48.41	22.34	70.15	53	53.35	46.79	7.16	49.27	44.00	26.01
USG 50 % p + 50 %, 15 DAT	42.56	48.45	48.94	23.64	72.58	54.92	49.82	7.19	49.64	44.35	26.41	26.86
USG 75 % p + 25 % PI	39.79	45.77	45.32	20.41	65.73	50.22	41.26	7.12	46.14	41.09	22.95	23.51
U 75 % p + 25 % PI	39.56	46.06	44.66	19.34	64.00	48.88	39.10	7.06	45.83	41.46	22.66	23.87
Mean*	40.60	46.69	46.41	20.59	66.92	50.96	42.75	7.14	47.12	42.17	23.96	24.69

* Mean of the 7 treatments excluding control.

50

Fig.10 a. NITROGEN UPTAKE BY GRAIN & STRAW

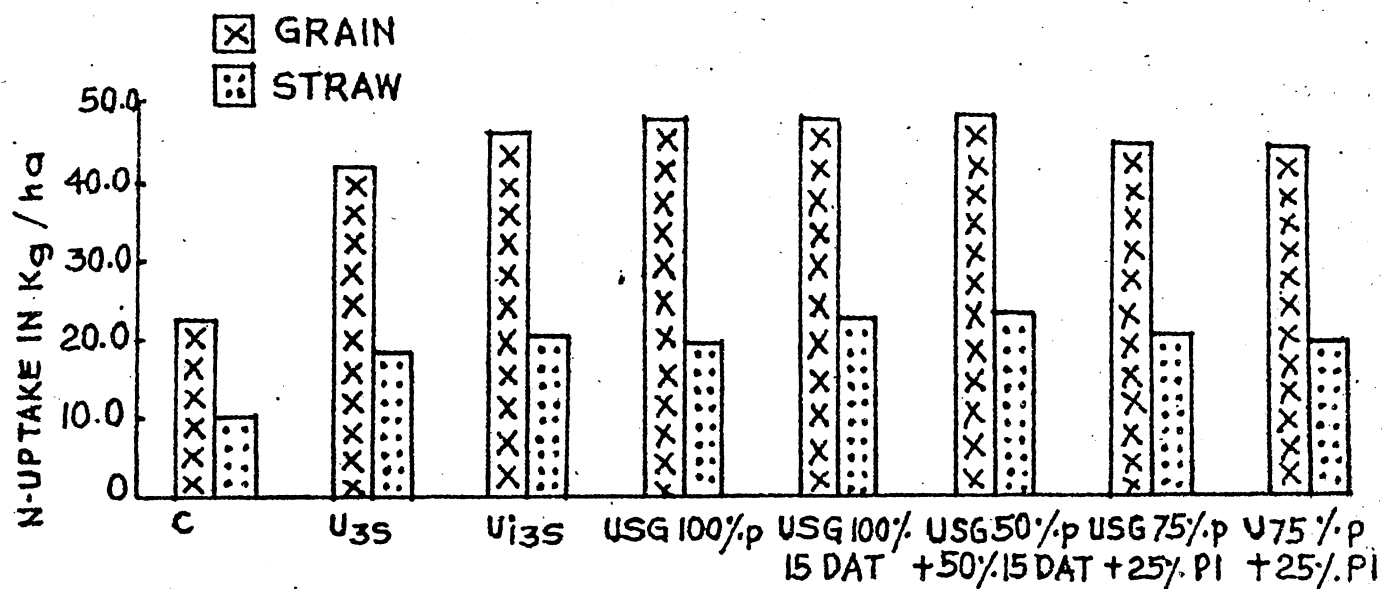


Fig.10.b. RECOVERY OF APPLIED NITROGEN

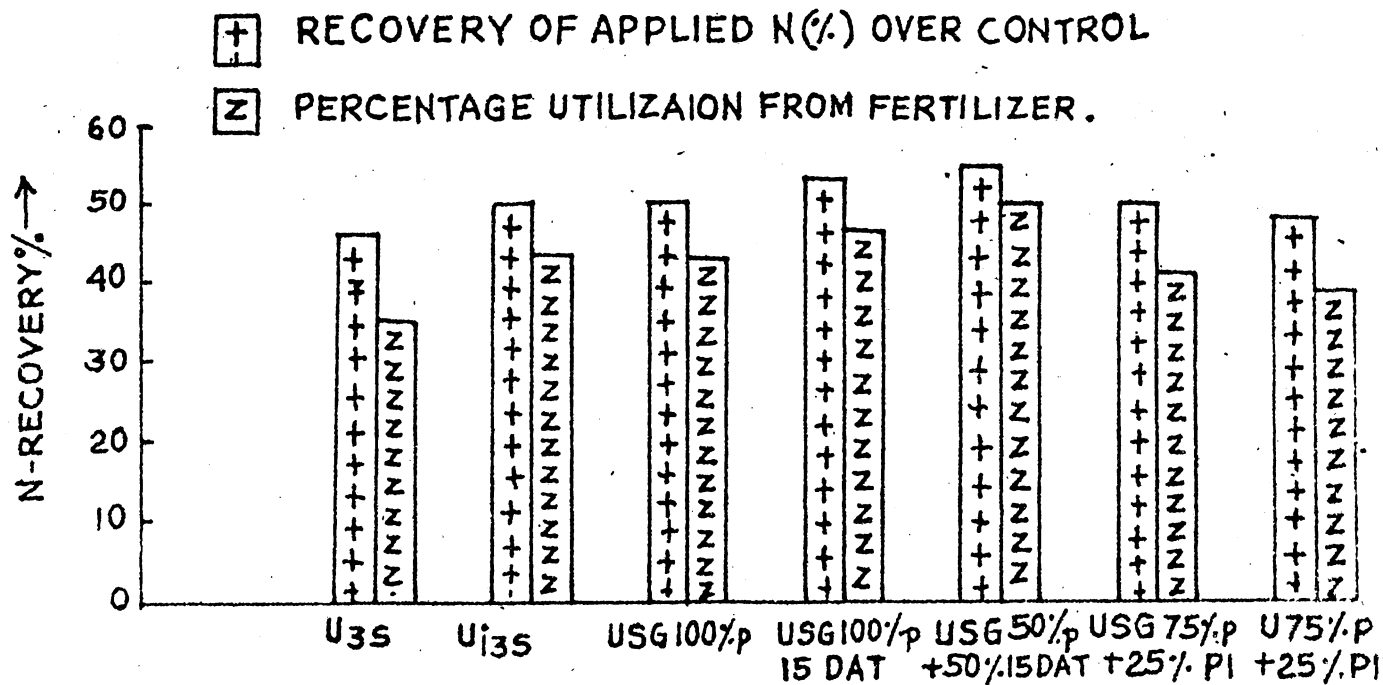


Fig.10.c. NITROGEN USE EFFICIENCY



Fig. 10(b). The average recovery over control was found to be 50.96 % and from fertilizer 42.75 %. A recovery percentage of 54.92 was found superior in the treatment where USG applied 50 % basal and 50 % at 15 DAT. Recovery from fertilizer was also found more (49.82 %) in this treatment. The recovery from urea, applied in 3 splits was found very poor (35.43 %).

4. Protein Content

The protein content in the grain was found to be 7.14 % in the treatments where 80 kg nitrogen was applied but only 6.55 % in the control treatment having no nitrogen.

5. Nitrogen Use Efficiency

The nitrogen use efficiency is presented in Table 13 and illustrated in Fig. 10(c). The nitrogen use efficiency was found to be 26.41 and 26.86 kg grain and straw respectively in the treatment where nitrogen applied in 2 splits i.e., 50 % basal and 50 % at 15 DAT. This treatment was found to be superior than any other treatment. The average nitrogen use efficiency was found to be 23.96 and 24.69 kg grain and straw respectively.

D. IRRIGATION STUDIES

1. Rainfall

During the period from 6th March to 31st May the crop remained in the field. There was 10.5, 44.3 and 44.1 mm rain during 1st, 2nd and 3rd phases of growth respectively. These quantities are however, were not considered effective for all the treatments. The treatment (M_1) (0 - 0.8 bar) received total rainfall of 10.5 mm (7th, 21st and 29th March) was considered effective since the quantity was less than evaporative demand. During 2nd phase from the 44.3 mm rain (9th, 10th, 23rd April and 1st May) only 26.8 mm was considered effective based on evaporative demand and the irrigation prior to rainfall. During 3rd phase 34.8 mm of the 44.1 mm rainfall was considered effective. Thus, from the total rainfall of 98.9 mm in the crop growth period, only 72.1 mm (72.90 %) was considered effective.

In other treatments, where standing water was necessary, the entire rainfall was taken to be effective.

2. Irrigation Requirement

Quantities of irrigation water applied at different stages of growth are presented in Table 14.

TABLE 14. IRRIGATION WATER APPLIED (mm) TO DIFFERENT TREATMENTS

Particulars	1st stage (33 days)	2nd stage (27 days)	3rd stage (27 days)	Total (87 days)
M_1	120 (6)	120 (6)	60 (3)	300 (15)
M_2	140 (6)	180 (6)	90 (3)	410 (15)
M_3	180 (6)	160 (6)	90 (3)	430 (15)
M_4	150 (3)	200 (4)	100 (2)	450 (9)
M_5	300 (3)	300 (3)	100 (1)	700 (7)
M_6	500 (5)	500 (5)	300 (3)	1300 (13)
Mean	231.67	243.33	123.33	598.33

Figures in parentheses indicate number of irrigations.

Water required for irrigation to maintain the moisture status varied with different treatments and was the minimum with the treatment M_1 (0 to 0.8 bar) and maximum with M_6 (draining once in a week). To maintain moisture at 0 - 0.8 bar throughout the crop season only 300 mm water was required as against 1300 mm required for the treatment where draining practised once in each week. The irrigation requirements for other treatments varied in between these two limits depending on whether saturated or submerged at different stages of growth. On an average the irrigation requirement was 231.67, 243.33 and 123.33 mm during 1st, 2nd and 3rd stages of crop growth, respectively and the average being 598.33 mm

About 15 irrigations were required to maintain soil moisture stress of 0 to 0.8 bar in M_1 . Each time the quantity of water applied was 20 mm. In M_2 and M_3 the same number of irrigations were required though the quantity of irrigation were different at each stage and at each irrigation.

3. Water Requirement of Crop

$$\text{Water requirement} = \text{Irrigation} + \text{Effective Rainfall}$$

Water requirements of different treatments at different stages are presented in Table 15. The average water requirement of rice variety 'Daya' during 87 days of growth in the field is 693 mm that varied from 372 mm in M_1 (soil moisture 0 - 0.8 bar) to 1399 mm in M_6 (10 cm standing water draining once in a week). The water requirement during 1st, 2nd and 3rd stages of growth were 242, 284 and 165 mm amounting to 35, 41 and 24 percent of the total requirement, respectively. In the treatment M_2 (saturation up to panicle initiation + 3 - 5 cm standing water till ripening) that produced the maximum grain and straw, the water requirements were 150.8, 224.3 and 134.1 during the 1st, 2nd and 3rd phases of growth, respectively totalling to 509 mm. When the field was maintained at

TABLE 15. WATER REQUIREMENT FOR DIFFERENT TREATMENTS

Particulars	1st stage			2nd stage			3rd stage			Seasonal total
	IR	ER	WR	IR	ER	WR	IR	ER	WR	
N ₁	120	10.5	130.5	120	26.8	146.8	160	34.8	94.8	372.1
N ₂	140	10.5	150.5	180	44.3	224.3	90	44.1	134.1	508.9
N ₃	180	10.5	190.5	160	44.3	204.3	90	44.1	134.1	528.9
N ₄	150	10.5	160.5	200	44.3	244.3	100	44.1	144.1	548.9
N ₅	300	10.5	310.5	300	44.3	344.3	100	44.1	144.1	798.9
N ₆	500	10.5	510.5	500	44.3	544.3	300	44.1	344.1	1398.9
Mean	231.67	10.5	242.16	243.33	41.38	284.71	123.33	42.55	165.88	692.76

IR = Irrigation Requirement
ER = Effective Rainfall
WR = Water Requirement.

0 to 0.8 bar soil moisture tension the water requirement was only 372 mm. When 10 cm standing water drained each week the water requirement was 1399 mm. In other treatments water requirement varied from 509 to 799 mm.

4. Water Use Efficiency (kg/ha cm)

Data on water use efficiency calculated by dividing the total dry matter and grain yield by water requirement are presented in Table 16 and illustrated in Fig. 11(a).

TABLE 16. WATER USE EFFICIENCY OF DIFFERENT WATER MANAGEMENT SCHEDULES

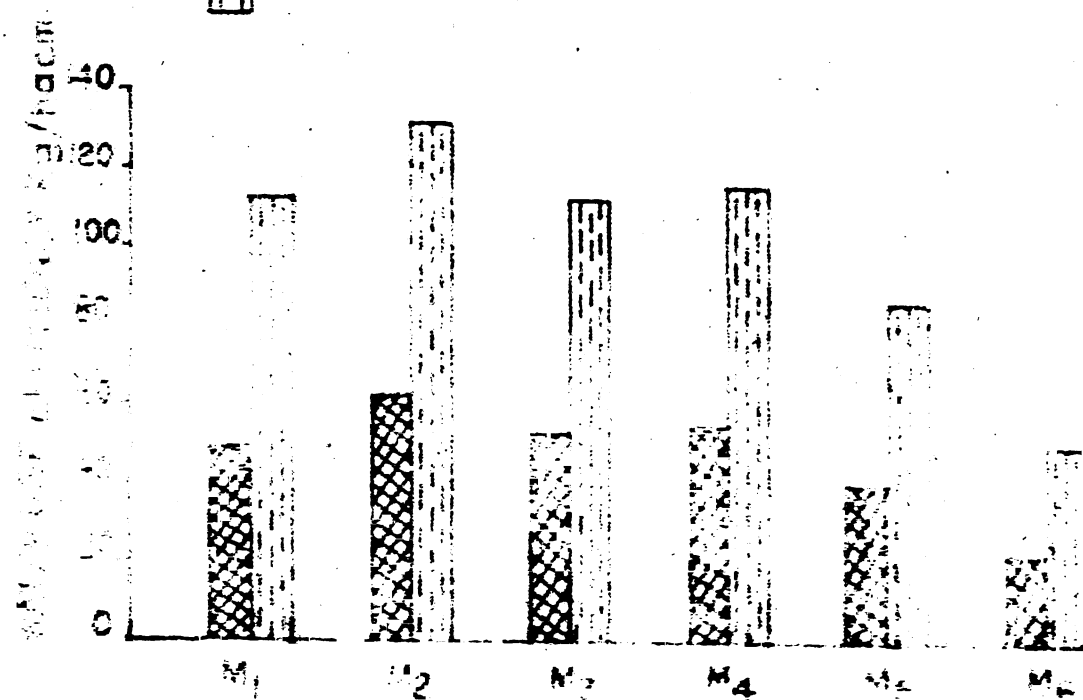
Parti- culars	Grain yield (q/ha)	Total yield (q/ha)	W.R.in cm	Water use efficiency (kg/ha cm)		Liter/kg	
				Grain	Total	Grain	Total
M ₁	28.49	64.58	57.21	49.79	112.88	2008.44	885.89
M ₂	44.39	93.78	70.81	62.69	132.44	1595.15	755.06
M ₃	38.65	82.63	72.89	53.03	113.36	1885.72	882.14
M ₄	40.98	86.80	74.89	54.72	115.90	1827.48	862.81
M ₅	40.19	86.46	99.89	40.22	86.55	2485.71	1155.40
M ₆	36.59	80.30	159.89	22.88	50.22	4370.63	1991.24
Mean			89.26	47.22	101.89	2362.19	1088.76

Water requirement includes 20 cm required for nursery and puddling (Lenka, 1976).

Fig. 11a.

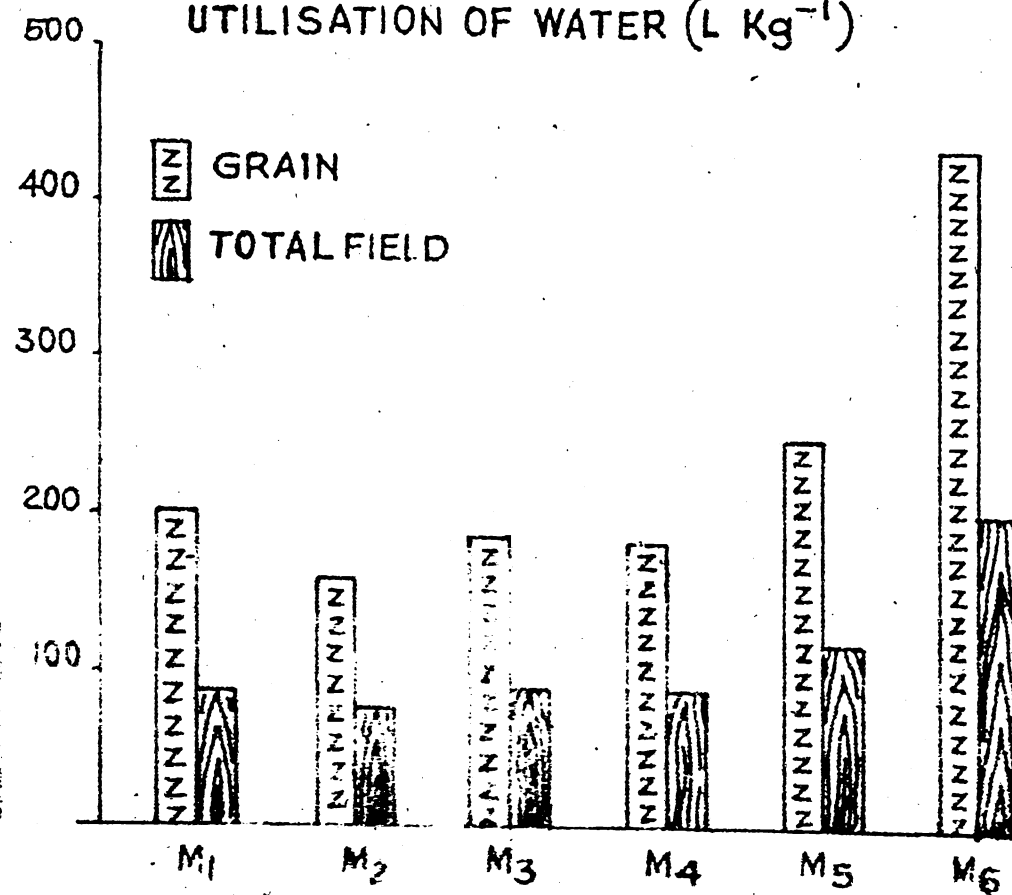
WATER USE EFFICIENCY

 GRAIN
 TOTAL FIELD



UTILISATION OF WATER (L Kg⁻¹)

 GRAIN
 TOTAL FIELD



The water use efficiency was calculated including 20 cm required for nursery and puddling. On this basis the average water use efficiency was 47.22 kg grains/ha cm. The water use efficiency was maximum i.e., 62.69 kg grains/ha cm when the field was kept saturated till panicle initiation followed by 3 - 5 cm submergence till ripening. The efficiency was the least in M_6 i.e., 10 cm standing water draining once in a week that produced only 22.88 kg grains/ha cm. Maintaining soil moisture at 0 - 0.8 bar throughout that consumed the least quantities of water had the water use efficiency of 49.8 kg grains/ha cm.

On the basis of total produce (grain + straw) the treatment M_2 proved most efficient that produced 132.44 kg dry matter. M_6 was found to be least efficient that produced only 50.22 kg dry matter per ha cm. The treatment M_1 (0 to 0.8 bar) produced 112.88 kg dry matter/ha cm.

To produce one kg grain and one kg total dry matter the water required found to be 2362.19 and 1088.76 litres, respectively. The treatment M_2 that produced the maximum grain and straw the water requirements were the least i.e., 1595 and 755 litres of water, respectively.

TABLE 17. WATER REQUIREMENT, EVAPORATION AND WR/PE RATIO

Weeks	Weeks ranged from	Evapora- tion in mm	M ₁ (WR)		M ₂ (WR)		M ₃ (WR)		WR/PE ratio		
			Weekly	Daily	Weekly	Daily	Weekly	Daily	M ₁	M ₂	M ₃
1	6 - 12 Mar.	30.1	20.7	2.95	30.7	4.38	30.7	4.38	0.69	1.02	1.02
2	13 - 19	37.5	27.3	3.90	27.3	3.90	27.3	3.90	0.72	0.72	0.72
3	20 - 26	33.9	25.33	3.61	25.33	3.61	29.6	4.22	0.74	0.74	0.87
4	27 - 2 Apr.	35.3	25.15	3.59	25.15	3.59	33.5	4.78	0.71	0.71	0.94
5	3 - 9	40.6	29.76	4.22	35.48	5.06	35.48	5.06	0.73	0.87	0.87
6	10 - 16	41.2	29.32	4.18	47.61	6.80	47.61	6.80	0.71	1.15	1.15
7	17 - 23	50.3	41.86	5.98	63.5	9.07	63.5	9.07	0.83	1.26	1.26
8	24 - 30	51.5	47.86	6.83	61.01	8.71	61.01	8.71	0.92	1.18	1.18
9	1 - 7 May	51.1	34.17	4.88	50.03	7.15	50.08	7.15	0.66	0.97	0.97
10	8 - 14	53.3	29.19	4.17	35.56	5.08	35.56	5.08	0.54	0.66	0.66
11	15 - 21	53.8	25.83	3.69	35.24	5.03	35.24	5.03	0.48	0.65	0.65
12	22 - 28	60.5	24.71	3.53	40.55	5.79	40.55	5.79	0.40	0.67	0.67

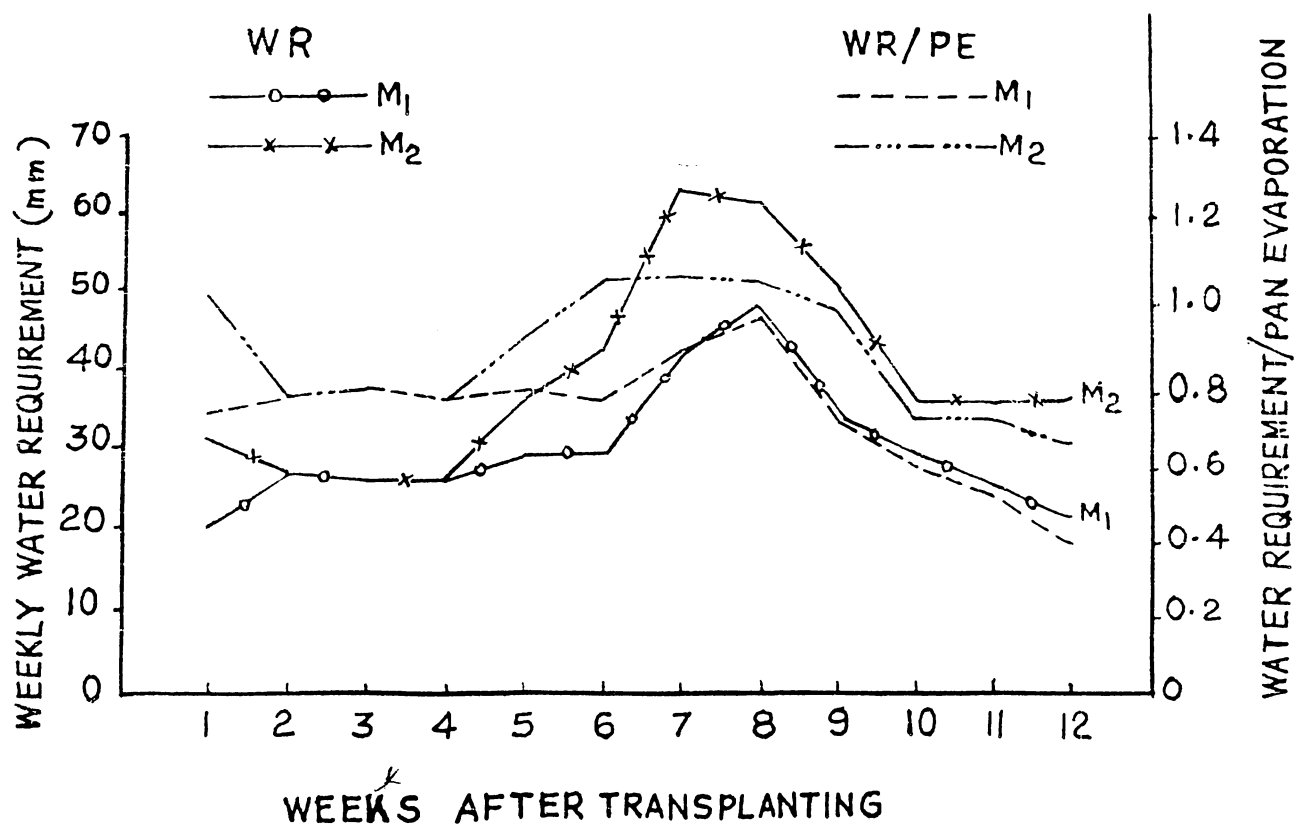
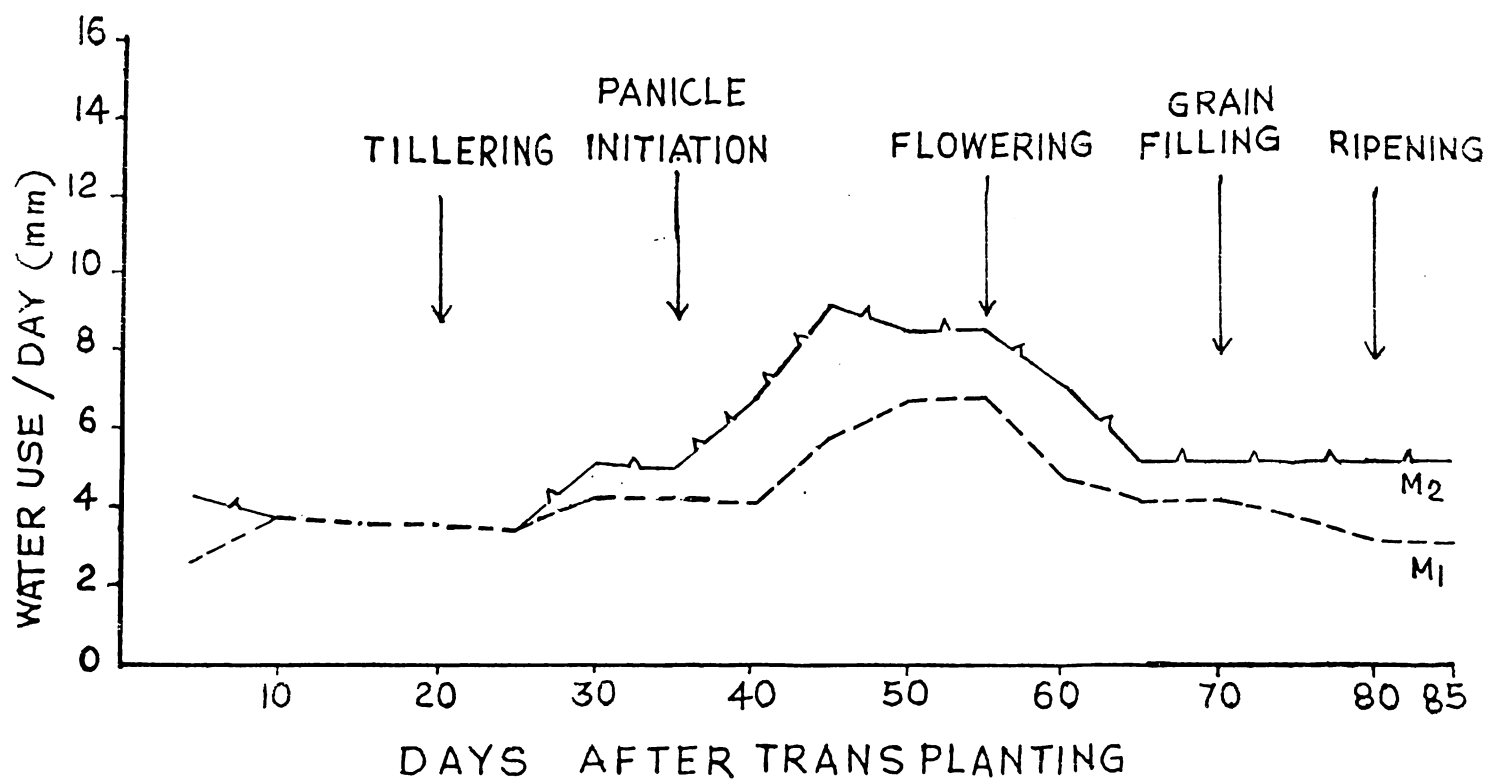
WR = Water requirement.

5. Daily, Weekly Water Requirement and WB/PE Ratio

Data on weekly water requirement of the crop in different treatments have been presented in Table 17 and illustrated in Fig. 11(b). Study of these would revealed that in M_1 the daily water requirement was about 3 mm/day in the beginning and increased gradually to the maximum of 6.93 mm/day coincided with flowering and reduced gradually to the value of 3.53 mm/day at ripening. In the treatment M_2 the daily water requirement remained almost same as in M_1 , up to panicle initiation stage i.e., 33 days after transplanting and varied subsequently due to maintenance of 3 - 5 cm standing water. After panicle initiation the value increased to 5.06 mm during 5th week and reached the maximum of 9.07 mm during 7th week and again decreased gradually to 5.03 mm towards ripening. When water was maintained 3 - 5 cm throughout, the daily requirements were 4.38 mm in the beginning shows similar trend like M_2 treatment towards ripening.

Compared with daily evaporation data as obtained from the USDA WB evaporation pan, it would be seen that in M_1 treatment the ratio of 0.70 in the beginning and increased to 0.93 at flowering and again decreased gradually to 0.45 at ripening. In the M_2 treatment, the maximum ratio was 1.26 during the period

Fig. IIb. DAILY & WEEKLY WR, WR/PE RATIO



from 17th to 23rd April decreased to 0.67 towards ripening. In M_3 , the ratios were at par with M_2 treatment. The water requirement and WR/PE ratio for M_1 and M_2 have been presented graphically in Fig. 11(b).

CHAPTER - V
DISCUSSION

D I S C U S S I O N

Data presented in previous chapter will indicate that growth, yield and quality of rice var "Daya" has been affected differently by water management and/or application of Urea, Super Granule Urea at different stages of growth either alone or with other carrier. In this chapter an attempt has been made to establish cause and relationship existing among these factors.

Water Management Practices

Scheduling irrigation has significantly affected the growth and yield attributing characters. Webster as defined growth as the progressive development of the plant parts. These plant parts directly and indirectly contribute to biological and economic yield of the crop, the latter being a differentiation product during the growth process.

Yield in rice is a function of number of tillers, effective tillers, length of the panicle, number of fertile grains per panicle, their size and weight. These characters are determined at different stages of growth. Unless the nutrient vis-a-vis management factors are adequate at the initiation and development stage of each character, subsequent manipulation of any kind, whatsoever, does not benefit it.

The maximum yield of 44.39 q grain and 49.39 q straw has been obtained from the treatment where saturation was maintained till PI and 3 - 5 cm standing water till ripening due to production of maximum number of effective ears (506) per sq.m having comparatively longer panicles of 16.9 cm with 78.6 fertile grains per panicle. Cumulative effect of such increased yield attributing characters resulted in the maximum yield. Maintenance of soil moisture 0 - 0.8 bar throughout restricted growth and development of the crop. The plant grew short, had fewer number of tillers with less dry matter of 734.4 g/m² produced the smallest panicles (15.97 cm) with the least (50.99) number of fertile grains, with lesser test weight of 18.8 g only which are responsible for low yield in this treatment. The study of water table data would indicate in these treatments the water stood 17 cm below the surface 15 days after transplanting that receded to 25 cm subsequently and was at 40 cm below surface at flower and ripening. Rice roots being mostly concentrated within 20 cm layer and being only horizontal in their character of ramification had lesser environment to tap for moisture and other nutrient. Nitrogen content in the plant 30 and 60 days after transplanting was less than those other soil moisture treatment which indicated not only moisture but also nitrogen was also limiting for growth and development of the plant. During summer season

when the plant grew under increasing evaporative demand of the atmosphere maintenance of moisture at 0 to 0.8 bar stress the plants and kept them incapable of absorbing nutrients sufficient to meet the requirement of adequate development. Matsushima et al. (1957) reported that the number of spikelets per panicle was directly proportional, so far as the range of the content was between 1.5 and 3.5 per cent, to the nitrogen content in the leaf blade during the period in which the number of spikelets is mostly determined (28 to 7 days before heading). Matsuura (1962) examined the relationship between the emergence of tillers and the nitrogen concentration and reported that an optimum concentration was 30 to 40 ppm and the lowest critical limit was 8 ppm. The concentrations observed in the treatments are well below the above values. Lenka (1976) have observed that during summer season continuous saturation is harmful and for good growth there should be standing water of 3 - 5 cm from PI till ripening. This treatment in the experiment has increased the plant height, effective tillers, panicle length, fertile grains and the test weight by 6, 39, 5.6, 35.11 and 11.92 per cent over those observed under 0 - 0.8 bar. Of all these the increase in effective ear bearing tiller and fertile grains has been spectacular. Moisture stress particularly at flowering has reduced the number of grains drastically either due to failure of pollination or development of

ovule. Similar effect of moisture stress on increased sterility has been reported by Rao (1971), Subramanian et al. (1978).

Study on evaporation data during the periods of growth would indicate that the average evaporation from open pan was 164.7, 147.6 and 251.0 mm during tillering, flowering and ripening. The relative loss of water from this treatment was 9.7 % below the PET which indicated that the crop was under soil moisture stress. Since cell division, enlargement and their successive growth phases are highly dependent on adequate moisture and nitrogen status, reduction in soil moisture content, definitely had affected adversely the crop growth and development. The concentration of DNA decreases with reduction in soil moisture content below field capacity and the crop growth was affected. Other water management schedules proved equally efficient because of their similar effect on growth and development characters. Continuous submergence of 3 to 5 cm had no beneficial effect over irrigation of 5 cm or 10 cm from the date of saturation observed. Similarly, maintaining 10 cm water and draining once in a week had no advantage. The superiority of maintaining soil moisture at about saturation followed by 3 - 5 cm, submergence has been reported by Lenka and Singh (1977), Kumar and Singh (1978). No standing water in the beginning

helped in increasing the tiller number and subsequent submergence helped in maintaining this, increase the panicle length and other yield attributing characters that ultimately resulted in maximum yield of grain and straw.

Nitrogen Management

Application of 80 kg N/ha either as Urea or Super Granule has increased the yield of grain and straw by 19.2 and 19.72 q/ha. It is due to corresponding increase in plant height (8.85 %), effective tiller (35.83 %), panicle length (7.58 %), number of fertile grains (35.53 %) and their weight (7.14 %).

Application of 80 kg nitrogen as Urea all applied in 3 splits increased the grain yield by 15.9 q and straw yield by 16.3 q over control due to corresponding increase in the growth and yield attributing characters. Incubation of Urea for 48 hours proved beneficial. Though the differences in grain and straw yield were not significant the increase was however 8.69 and 8.76 % more than 80 kg nitrogen as uninoculated Urea applied in 3 splits. These results are in close conformity with the findings of Sahu and Pal (1982). They observed that application of incubated Urea was found better than uninoculated Urea under Similighur conditions.

Application of UBG all at 15 DAT or UBG 50 % at planting + 50 % at 15 DAT proved equally effective

and were slightly superior to 3 split Urea but not superior to incubated Urea. When the differences at 1 % level are not significant, application of incubated urea in 3 splits can be considered equally effective as USG applied all at planting or in 3 splits.

Concentration of nitrogen in the plant parts 30 and 60 days after planting were 2.31 and 2.12 % as compared to 1.69 and 1.38 % in corresponding dates in control. This shows the crop absorbed more nitrogen when fertiliser source was present. This increased application of nitrogen helped in production of more dry matter through increased growth parameters that resulted in increased yield of grain and straw. Application of nitrogen either as incubated urea or as USG increased the nitrogen content in the plants at any stage of growth than in urea alone applied in 3 splits. Though differences in plant height and number of total and effective ear bearing tillers were not affected either as urea or USG. The differences were more conspicuous with respect to panicle characters. In most of the cases nitrogen concentration at 60 DAT was more in the plant due to application of USG, which might have helped in maintaining the flow of carbohydrates from source to the sink. Top dressing with CAN at panicle initiation supplementing USG or urea did not differ with respect to their content in the plant parts and consequently their effect on growth and development of characters did not vary markedly.

Uptake of Nitrogen

Analysis of data on uptake of nitrogen content in plant at 30 and 60 DAT and in grain and straw would indicate that the concentrations were 2.07, 1.96 and 1.13 in grain and 0.43 in straw. The reduction in concentration of nitrogen is attributed to dilution effect due to increased dry matter accumulated by the plants. By the 30th day when the plants were short had only 218 tillers per sq.m , the concentration was 2.23 due to irrigation of 5 cm on the date of saturation observed. This difference however levelled up subsequently and moisture maintained at 0 - 0.8 bar followed by 3 - 5 cm submergence accumulated more nitrogen in the plant parts that resulted in its increased content in grain and straw which resulted in maximum yield. The concentration of nitrogen in the grain was 1.146 % and in straw was 0.488 % in the M₂ treatment which was higher than other treatments irrigated 5 to 10 cm on the date of saturation observed or where 3 - 5 cm submergence followed throughout. From this point of view this scheduling of irrigation also appears better than others.

The crop with an yield of 21.43 q grain and 26.96 q straw per hectare removed 32.72 kg N/ha (22.45 kg through grains + 10.27 kg through straw). Application of 80 kg nitrogen increased the uptake to 66.92 kg N/ha (46.4 kg through grains and 20.3 kg through straw).

Application of nitrogen as incubated urea or super granule increased recovery to the extent of 6 % more than from that as urea alone. Application of USG at 15 DAT or as USG 50 % at planting + 50 % at 15 DAT increased the recovery by another 3 % which is due to increase in yield of grain and straw though the concentration did not vary. Data reported by Yamada et al. (1979), Prasad (1980), Craswell et al. (1981), Juang (1982) show that rice crop recovers more nitrogen from USG as compared to urea alone and hence application of USG can be recommended to increase the efficiency of nitrogen utilization.

The efficiency of nitrogen utilization highest (26.4 kg grain) when USG applied 50 % as basal and 50 % at 15 DAT. Similar increased efficiency of nitrogen utilization due to application as USG has been reported by Li and Chen (1980), Marumoto (1981). The variation in uptake is due to variation in yield than that due to concentration.

Irrigation and Water Requirement

The rice variety "Days" grew in the field for 87 days from transplanting to ripening under the conditions of increasing evaporative demand. The average duration of the three phases of growth were 33, 27, 27 days. During this period the evaporations were 164.7 mm.

147.6 mm and 251 mm and rainfall of 10.5 mm, 44.3 mm and 44.1 mm (Appendix-3). The atmospheric mean temperature during corresponding periods were 29.65°C, 30.45°C and 31.7°C and the mean relative humidity 74 %, 68.5 % and 67.5 %. The average irrigation requirement during the 1st, 2nd and 3rd phases were 231.67, 243.33 and 123.33 mm. Adding the effective rainfall of 10.5, 41.38 and 42.5 the average total requirement found to be 692.76 mm. The quantity was the least (372 mm) in the treatment that was maintained at 0 to 0.8 bar and the maximum (1398.9 mm) in the treatment due to draining of standing water every week. From the efficiency point of view maintaining soil at about saturation up to panicle initiation and 3 - 5 cm water till ripening proved the best. In this treatment the average water requirement was 508.9 mm with an efficiency of 62.69 kg grain, 69.75 kg straw per ha cm. Though the water requirement was more in the treatment M_6 , 22.88 kg grain and 27.36 kg straw per ha cm, the efficiency was less due to lesser number of tillers, poor growth and development of the plant. Similar values with the average requirement of the crop was reported by Lenka and Singh (1977).

WR/PE ratio of rice plant varied with the treatments (Table 17). The ratios were 0.69 after

transplanting, that reached the maximum value of 0.92 at flowering in the treatment 0 - 0.8 bar soil moisture. These low ratios are due to the fact that the moisture content was suboptimal in this treatment. Maintaining standing water in the field increased this ratio to 1.26 at flowering which indicated that if water is not limiting this ratio can be more than unit unlike the operations recorded in other dry crops. This was due to high evaporative demand of the atmosphere characterised with high temperature and low humidity. The potential variation between soil and atmosphere is from 0 to 1250 bars.

In this experiment the average water use efficiency 47.22 kg grain and 54.67 kg straw per ha cm of water. Reduction of soil moisture content to 0.8 bar has harmed the crop as supported by poor vegetative and reproductive growth parameters, that produced the least yield of grain and straw. In this case least evaporative surface has not resulted in greater efficiency because of drastic reduction in yield of sink and source, whereas the efficiency was maximum (62.69 kg grain/ha cm) where moisture was maintained at saturation till panicle initiation and 3 - 5 cm standing water till ripening. This was due to proportionately greater increase in growth and yield parameters as compared to other treatments.

Irrigating 10 cm every week and draining proved least efficient and unnecessary. This treatment has neither been proved useful from improving the rhizosphere microclimate from the chemical point of view nor useful from water requirement point of view.

CHAPTER -VI

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

To find out suitable water management practice and the effect of urea and super granule urea and their time of application on rice an experiment was conducted with cv. 'Daya' (120 days) in sandy loam soil with high water table assigning the practice of water management to main plots and nitrogen management to subplots during the period from February - May, 1983 at the Central Research Station of the Orissa University of Agriculture and Technology, Bhubaneswar. The following are the salient findings of the experiment.

- (1) Maintaining soil moisture 0 to 0.8 bar throughout the crop growth period proved harmful, it reduced growth and development of the crop and produced the least yield of 28.49 quintal grain and 36.09 quintal straw per hectare.
- (2) Shallow submergence of 3 - 5 cm after panicle initiation proved beneficial but throughout the life cycle was found not necessary.
- (3) Maintaining soil moisture at about saturation from transplanting till panicle initiation (33 days) followed by 3 - 5 cm submergence

till ripening proved the best water management schedule which resulted in maximum ear bearing tillers per sq.m with the highest dry matter content that resulted in the longer panicles with maximum number of fertile grains weighing 21.71 g/1000 and consequently produced maximum yield of 44.39 quintals grains and 49.39 quintals straw per hectare.

- (4) Application of 80 kg nitrogen increased the grain yield by 19.2 quintals and straw yield by 19 quintals per hectare over control (21.43 and 26.96 q/ha grain and straw, respectively).
- (5) Incubation of urea with soil increased its efficiency. Application of 80 kg nitrogen applied as incubated urea and super granules proved equally effective producing 40.85 q grain and 47.39 q straw and 42 q grain, 48 q straw per hectare respectively which are 2 and 5 quintals more than urea though the differences were not significant.
- (6) Application of incubated urea in 3 splits proved equally effective as application of

urea super granules all at planting, USG 15 days after or 50 % nitrogen as USG at planting and the rest as USG 15 DAT.

- (7) Top-dressing 25 % nitrogen as CAN at panicle initiation proved inferior to application of 80 kg nitrogen as incubated urea in splits.
- (8) Under unfertilized conditions the crop yielding 21.43 q grains and 26.96 q straw removed 32.72 kg nitrogen (22.45 kg through grain and 10.27 kg through straw). Application of 80 kg nitrogen increased the yield to 40.60 q grain and 46.69 q straw removed 66.92 kg nitrogen (46.41 kg through grain and 20.59 kg through straw). Recovery of nitrogen from urea was 35 % and increased to 43 % due to incubation. It increased further to 46 - 47 % when nitrogen was applied as urea super granules. The average response was 24 kg grain and 25 kg straw per kg nitrogen.
- (9) The rice variety 'Daya' in 87 days in the field required 89.26 cm water including 20 cm required for nursery and puddling. The water use efficiency was about 47.22 kg grain/ha cm. The WR/PE ratio varied from 0.69 after transplanting to 1.26 at flowering that reduced to 0.40 at ripening.

C O N C L U S I O N

Maintenance of soil moisture at about saturation till panicle initiation followed by 3 - 5 cm submergence till ripening is the most desirable and efficient water management practice under high evaporative demand and low water table conditions prevailing during dry season. The crop required 71 cm water and the water use efficiency was 63 kg/ha cm. Nitrogen use efficiency can be increased by incubating urea with soil or by applying it as super granules. The average nitrogen use efficiency from fertilizer source was 40 % and the response was 24 kg grains/kg N. The production of 40.60 q grain and 46.69 q straw removed 66.92 kg nitrogen per hectare.

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* Originals not seen.

APPENDIX

APPENDIX - I

ANALYSIS OF VARIANCE (MEAN SQUARES) FOR DIFFERENT CHARACTERS

Characters	Replication d.f. = 1	Water management d.f. = 5	Error(a) d.f. = 5	Nitrogen management d.f. = 7	Ma x Mn 35	Error (b) 42
1	2	3	4	5	6	7
<u>Height of the plant</u>						
(a) 15 DAT	6.843*	17.806*	0.516	15.387*	2.363*	1.425
(b) 30 DAT	2.303*	47.373*	0.236	7.737*	2.225*	1.316
(c) 45 DAT	0.013	62.237*	3.345	15.750*	1.662	4.309
(d) 60 DAT	0.782	57.292*	2.292	36.409*	2.958	3.535
(e) At harvest	6.053	70.235*	0.981	41.517*	2.750	3.544
<u>Number of tillers/m²</u>						
(a) 15 DAT	113.766	2826.249*	210.098	7099.46*	369.367	391.569
(b) 30 DAT	6418.600*	5483.386*	598.618	13865.226*	378.385	1092.674
(c) 45 DAT	3862.930*	11821.912*	2088.726	12343.107*	1087.134	857.868
(d) 60 DAT	870.1	15484.486*	854.518	12588.559*	903.033	761.091
(e) At harvest	8034.62*	74523.57*	700.516	46180.371*	2242.256	4807.769

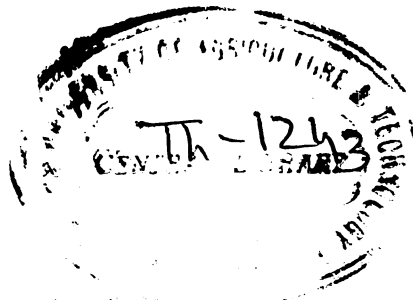
	1	2	3	4	5	6	7
<u>Dry matter production/m²</u>							
(a) 30 DAT		522.708	3116.925*	176.333	6611.667*	347.677	369.324
(b) 60 DAT		1717.08	32665.374*	593.81	252515.21*	1343.161	2307.545
<u>Panicle characters</u>							
(a) Length of panicle		9.964	6.213	1.511	3.494*	0.710	0.637
(b) Total number of grains/panicle		14.10	1294.864*	32.032	1491.031*	84.194*	42.152
(c) Number of fertile grains/panicle		93.81	1847.606*	52.578	1544.265*	61.336	32.694
(d) Percentage of fertile grains (Angular)		16.93	145.63*	12.208	72.963*	6.709	5.628
(e) Test weight		0.827	7.935*	0.431	4.616*	0.216	0.435
<u>Yield studies</u>							
(a) Grain yield		2.095	12.825*	1.393	15.975*	0.287	0.925
(b) Straw yield		2.227	8.698*	0.984	16.824*	0.578	1.406
(c) Grain : Straw ratio		0.001	0.025*	0.002	0.008	0.004	0.005
(d) Harvest Index (Angular)		0.030	7.866*	0.696	2.383	1.212	1.369

* Significant at 5 %

APPENDIX - II

DATES OF IRRIGATION OF THE DIFFERENT TREATMENTS

Particulars	Dates of irrigation														
N_1	8.3.83	13.3	18.3	26.3	1.4	6.4	13.4	18.4	22.4	26.4	29.4	3.5	7.5	18.5	24.5
N_2	8.3.83	13.3	18.3	26.3	1.4	6.4	13.4	18.4	22.4	26.4	29.4	3.5	7.5	18.5	24.5
N_3	8.3.83	13.3	18.3	26.3	1.4	6.4	13.4	18.4	22.4	26.4	29.4	3.5	7.5	18.5	24.5
N_4	8.3.83	-	18.3	-	1.4	-	13.4	-	22.4	26.4	-	3.5	-	18.5	24.5
N_5	8.3.83	-	18.3	28.3	-	-	18.4	-	26.4	-	3.5	-	18.5	-	
N_6	8.3.83	14.3	20.3	26.3	1.4	7.4	13.4	19.4	25.4	1.5	7.5	13.5	19.5		

APPENDIX - IIIDAILY RAINFALL AND EVAPORATION IN mm DURING
CROP GROWTH PERIOD

Dates	Months					
	March		April		May	
	Rain fall	Evaporation	Rain fall	Evaporation	Rain fall	Evaporation
1	-	2.9	-	5.5	1.2	3.1
2	-	4.1	-	4.6	-	6.3
3	-	4.0	-	5.3	-	8.7
4	-	4.2	-	4.1	-	8.8
5	0.2	3.2	-	5.9	-	7.0
6	-	4.3	-	4.3	-	10.0
7	0.7	2.5	-	8.3	-	7.2
8	-	3.4	-	6.9	1.7	10.1
9	-	3.7	2.2	5.8	2.0	5.6
10	-	4.7	8.9	6.3	2.0	9.7
11	-	5.5	-	6.0	-	8.5
12.	-	6.0	-	6.2	-	6.7
13	-	4.6	-	5.1	11.2	6.7
14	-	5.9	-	6.6	9.0	6.0
15	-	5.6	-	6.0	-	7.9
16	-	6.8	-	5.0	-	9.1
17	-	3.8	T	6.2	-	6.1
18	-	4.8	-	5.4	-	8.3
19	-	6.0	-	5.5	-	8.5
20	-	5.4	-	6.1	-	6.8
21	9.2	7.7	-	6.5	-	7.1
22	-	2.8	-	4.9 (Cyclone)-	-	9.5
23	-	4.2	32.0	13.7	-	10.3
24	-	3.9	-	5.7	-	9.3
25	-	3.9	-	6.9	-	7.9
26	-	6.0	-	6.7	T	7.0
27	-	4.8	-	6.9	-	8.5
28	-	5.1	-	8.6	-	8.0
29	0.6	4.7	-	8.6	18.2	8.9
30	-	6.0	T	8.1	-	8.4
31	-	4.6	-	-	-	6.9