

PHYSIOLOGICAL ANALYSIS OF GROWTH AND YIELD OF WHEAT
AS INFLUENCED BY FERTILITY LEVELS

By

BHASKAR DAULAT MESHRAM

Reg No 93032

A thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI-413 722, DIST AHMEDNAGAR
MAHARASHTRA STATE (INDIA)

in partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

PLANT PHYSIOLOGY

DEPARTMENT OF BOTANY

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI, DIST AHMEDNAGAR
MAHARASHTRA (INDIA) 413 722

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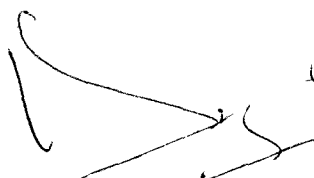
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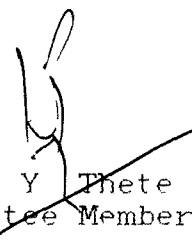
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DEPARTMENT OF BOTANY

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I hereby declare that this thesis or part
thereof has not been submitted by me
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Place Rahuri

Dated 7 / 7 / 1997



(BHASKAR D MESHARAM)

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C E R T I F I C A T E

This is to certify that the thesis entitled,
"Physiological analysis of growth and yield of wheat as
influenced by fertility levels", submitted to Post Graduate
Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist
Ahmednagar in partial fulfilment of the requirement for the
degree of **MASTER OF SCIENCE (AGRICULTURE)** in **PLANT PHYSIOLOGY**
embodies the results of a piece of bona fide research work
carried out by **Mr. MESHARAM BHASKAR DAULAT** under my guidance
and supervision and that no part of the thesis has been
submitted for any other degree or diploma or publication

The assistance and help received during the course
of this investigation and source of literature referred to
have been duly acknowledged

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C E R T I F I C A T E

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Place - Rahuri

Dated 9/7/1997


V M Pawar

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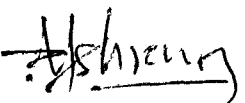
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Dated 7 / 7 / 1997


(B D Meshram)

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ABBREVIATIONS USED

| | |
|-------|-----------------------|
| SE | Standar error |
| N S | Not significant |
| C D | Critical differences |
| Cv | Cultivar |
| cm | Centimeter |
| mg | Miligram |
| g | gram |
| q | quintal |
| dm | Decimeter |
| ha | Hectare |
| DAS | Days after sowing |
| t | tonnes |
| % | per cent |
| N | Nitrogen |
| P | Phosphorus |
| K | Potassium |
| NAR | Net assimilation rate |
| AGR | Absolute growth rate |
| RGR | Relative growth rate |
| sq m | Square meter |
| LAI | Leaf area index |
| LAD | Leaf area duration |
| HI | Harvest index |
| viz , | Vide licent (namely) |

ABSTRACT

PHYSIOLOGICAL ANALYSIS OF GROWTH AND YIELD OF WHEAT
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By

BHASKAR DAULAT MESHARAM

A candidate for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

Mahatma Phule Krishi Vidyapeeth,
Rahuri 413 722

1997

Research Guide

Prof B P Deore

Department

Agricultural Botany (Plant Physiology)

A field trial entitled "Physiological analysis of growth and yield of wheat as influenced by fertility LEVELS", was conducted at Instructional Farm, Department of Botany, Central Campus, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist Ahmednagar (M S) during Rabi season of 1993

An experiment was laid out in a Factorial Randomised Block Design (FRBD) with four replications. In this experiment, three varieties with two fertilizer levels were used

The observations on different morphological characters, dry matter studies, days required for different growth stages, growth functions, post harvest studies and

Abstract contd .

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chemical analysis of plant parts as well as soil analysis before and after the crop were recorded

The studies revealed significant differences have been observed in most of the observations but interactions found not significant in some cases

It can, therefore, be concluded that the yield of wheat can be increased with increase in the fertility level. The influence varied with varieties, fertilizers and their concentrations. Thus, fertilizer level 100 60 60 NPK kg/ha gave higher grain yield than fertilizer level 50 30 25 NPK kg/ha. This increase in yield was mainly because of the increase in yield contributing attributes, such as productive tillers, number of ears per plant and thousand grain weight

Chapter Opener Page

Introduction

1 . INTRODUCTION

Wheat (Triticum aestivum L.) is one of the most widely cultivated rabi cereal of the world and India. It is an important staple food of the two third world's population. It is called as the king of centrals in temperate world, as well as, it is equally important in the semi-tropical regions of India. In India, wheat is eaten in various forms and make a large contribution to the calories and protein available to human beings than any other cereals. Recently wheat is being used for processed food products and the demand for these products is increasing very fast. Besides staple food for human beings, wheat straw is also used as a cattle feed in our country. Wheat contains more protein (8-12 %) than other cereals and also it contains niacin and thiamine. 'Gluten' present in wheat is very essential for bakers.

Growing of wheat in India began very early in the prehistoric times and it seems that its centre of origin is South western Asia. It is believed that Aryans brought wheat grains to India, since then it has been cultivated in India. A turning point came in the history of wheat in 1963 with the introduction of dwarf, photosensitive, high yielding maxican wheat breeding material developed by Nobel Laureate, Dr Norman E Borlag. In Rabi, 1964 these varieties were tested at 155 locations under all India Co-ordinated wheat Improvement Project, where Larma Rajo and Sonora-64 out

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yielded local tall wheat varieties. As a result in 1965 both these varieties were released for general cultivation in wheat growing areas of India. After some time these varieties were replaced by amber seeded high yielding varieties like Kalyansona and Sonalika. In 1970, triple dwarf varieties were released and since then so many dwarf varieties have been evolved for cultivation in different agro-climatic zones in India.

In India, area under wheat cultivation was 230.63 lakh hectares in 1987-88 which increased to about 232.62 lakh hectares in 1991-92 and production rose very rapidly from 461.69 lakh tonnes in 1987-88 to about 550.87 lakh tonnes in 1991-92 (Anonymous, 1992-93). In Maharashtra, the final area forecasted during 1993-94 was 753 thousands hectares and tentative area during 1994-95 was 750 thousand hectares. Final forecasted production during 1993-94 was 1056 thousand tonnes. The area under wheat crop in India was 23644 thousand hectares and in Maharashtra it was 781 thousand hectare during 1991-92 which was only 3.3 per cent. The total production in India was 8,46,303 thousand tonnes and in Maharashtra it was 78,937 thousand tonnes which was 9.3 per cent (Anonymous, 1994-95). By considering population hazards, the Malthus theory of 'The population' touch to the mind. He stated that the food grain increases arithmatically (1,2,3) while the

population increases geometrically (2,4,8,16) so, to supply the food for these population there is need to minimise the research gap i.e. the gap between theoretical yield potential estimated by production physiologists and the highest yield obtained so far on a research farms by using high yielding dwarf varieties and optimum levels of fertilizers

Crop yield is a net result of various closely interlinked metabolic processes of the plant and analysis of which therefore involves various physiological processes. The economic yield can be considered as the weight of an organ or a substance harvested from a plant and as such forms only a little production of its total dry matter. Understanding the control of economic yield in physiological terms need knowledge of which part of system of the crop acts as the source of the dry matter for economic yield. It is also obvious that understanding the factors influencing photosynthetic efficiency and further partitioning of the dry matter produced between economically useful and other parts of the plants and lastly the dependence of the whole system on environmental factors, would assume great significance

Stability of development of each genotype in various environment implies the physiological adjustment and

the capacity of such adjustment is the property of that genotype. This capacity of individual is changed with change in environment such as different fertility levels (Soil, air moisture and nutrient status), light and temperature (minimum and maximum) being supplied. Thus, each genotype reacts differently with different cultivation practices and crop management such as sowing time, depth of sowing, seeding rate and spacing, nutrient supplied etc.

Yield of wheat is dependent on two grain yield components i.e. the effective number of ears per unit area and the grain weight per ear. Both these components are further indirectly or directly dependent on the number of other characters like grain number per ear, grain size, survival percentage of tillers, number of fertile spikelets etc. All other characters remaining constant increase in any one or more of them will increase the yield.

In cereals, as in many crops, plant density is the most important yield determining factor which can be manipulated to attain the maximum production from an unit area. Besides plant density, adequate fertilization of nitrogen and phosphorus is most important. Among the various factors affecting the yield of the crop, nitrogen, phosphorus and potassium application can be considered as one of the important factors in determining the yield potential of

various dwarf wheats. The reduction of ear size or limit to ear number per unit area at the time of harvest with increasing plant population is expected to be due to nutritional and/or translocational limit. Different optimum N, P, K doses of fertilizer per hectare for maximum wheat yield have been recommended by different workers. They have further reported that this response varies with different varieties.

It is necessary further to study the causes of reduction in the yield with increase or reduction in the fertilizer levels. Analysis of physiological parameters will help to solve this. A study of plant types viz., different varieties of wheat crop is also necessary in this regards. It is also important to assess how far fertilizer status of plant influence the translocation of photosynthates from assimilating organs to the developing grains as well as vegetative part (biological yield) and also to evaluate the interactions between genotypes and fertility levels, so as to increase the economical yield as well as biological yield with nutritional value of the yield improvement in wheat.

Earlier workers attempted to study the morphological characters. According to Thorne (1966) the most obvious character likely to give large grain yield is the sample leaf area after ear emergence. The research on the

physiology of grain yield in cereals was focused upon the productive capacity of photosynthetic system during grain filling and particular interest has been centred around the capacity of the ear to use assimilates. These facts emphasized the need to study the efficiency of dry matter production with the nutrients available and differential nutrient uptake as shown by the concentration or total content of the element in shoots. These studies are of great significance for better elucidation of responsiveness of any variety in terms of physiological determinants

The increase in wheat production and average per hectare yield was responsible because of introduction of high yielding dwarf varieties of wheat and fertilizer level influence the crop. In view of these considerations the present studies "Physiological analysis of growth and yield of wheat as influenced by fertility" levels were undertaken and the main objectives being as below

- 1 To study the physiological basis for varietal differences in yielding ability among genotypes.
2. To study the dry matter production and its partitioning in different plant parts.
- 3 To study the growth functions of different genotypes.
4. To study the effect of fertilizers on physiological parameters.

Chapter Opener Page

*Review of
Literature*

2 . REVIEW OF LITERATURE

Majority of research workers have observed that wheat varieties differ from each other in respect of physiological characters namely, height of plants, tillering, leaf area and number of leaves etc. It has also been reported that yield contributing characters such as productive tillers, number of grains per ear, spikelets per ear, length of ear and 1000 grain weight differ from variety to variety in the same species. However, these differences lead to the differences in yield due to the influence of various fertility levels. Therefore, attempts are made to summarize the literature on differences in varietal characters and effect of fertilizer levels in respect of growth and yield of wheat crop.

2.1 Growth studies

Langer and Liew (1973) reported that nitrogen application had a large effect on the leaf area duration (LAD) but the grain/leaf ratio was depressed.

Khalifa (1973) carried out the growth analysis and indicated that the variation in the grain yield was mainly a reflection of the effect of the treatments on leaf area duration (LAD) after ear emergence. Early nitrogen application effectively increased LAD by increasing LAI toward the time of emergence, while late nitrogen had very little effect on LAI and consequently on LAD after ear emergence.

Ray et al (1989) studied the response of wheat and barley to nitrogen and reported that wheat plant height and spike length and barley plant height were greatest with 220 kg nitrogen

Silberbush and Lips (1991) studied the potassium, nitrogen, ammonium/nitrate ratio, the sodium chloride effect on wheat growth in pot culture. They reported that tiller number/plant was correlated with dry matter yield and increased with nitrogen concentration of NH_4^+ NO_3^- ratio

2.2 Dry matter studies

Srivastava and Mehrotra (1975) stated that proper combination of fertilizers with high yielding varieties occupies a unique place. Maximum absolute quantity of nitrogen was absorbed between seedling and late tillering stage, while the absolute quantity of dry matter production was maximum between flowering and milk stage. Varieties showed more marked variation in the rate of growth in dry matter production during reproductive phase. Thus, 32 per cent of the total dry matter was recorded between flowering and milk stage in Sonalika when Kalyansona and UP-301 had accumulated only 24 per cent and 26 per cent, respectively. At late tillering stage, more than 50 per cent of the total nitrogen was taken up while only 22 per cent of the total dry matter had accumulated.

Blum (1985) reported that the differences between varieties and between species in total ear carbon exchange rate (CER) and transpiration were associated largely with differences in ear surface area rather than with the rate per unit area. Rates of CER and transpiration per unit area of ears were 40-80 per cent of these flag leaves depending on species. The contribution of awns to total ear CER depended largely on total awn surface area/ear, rather than on CER per unit awn area. Awns contributed about 40-80 per cent of the total spike CER depending on the species but only 10-20 per cent of the spike transpiration. It was concluded that a large proportion of awns in the ear is a drought adoptive attribute in these cereals, for which tetraploid wheat exceeded hexaploid wheat.

ZHU et al (1986) studied the physiological parameters in relation to premature senescence in winter and they observed that nitrogen content per unit leaf area, nitrate reductase activity of the main flag leaf, harvest index, daily 1000 grains weight increament and root activity were measured during premature senescence in three winter wheat cultivars

Gehl et al (1990) studied the effects of incremental nitrogen fertilization on grain yield and dry matter accumulation of six spring wheat cultivars in Southern

Manitoba. They reported that N application increased the grain and straw yields of cultivars. The predominant factor affecting the N response and harvest index of each cultivar dependent on available soil moisture.

Papakosth and Gagionas (1991) concluded that greater the amount of dry matter and nitrogen accumulated before anthesis, higher the translocation rate of dry matter to grain and greater the risk of net nitrogen loss at maturity.

Martin et al (1991) studied the dry matter and nitrogen relocation in T. aestivum as affected by nitrogen levels and timings of application. They reported that spike fertility values and the caryopsis dry matter accumulation pattern were calculated and it was observed that grain yield per stem was affected by number of differentiated values during the preanthesis period rather than by caryopsis weight because of existence of a physiological limit to caryopsis storage capacity. An optional crop nitrogen status was the decisive factor at the preanthesis stage for ovule differentiation, while post anthesis N status determine the number of caryopsis set in each inflorescence and the availability of assimilates. Higher N content of rachis and glumes in late fertilized plant suggested an opportunity for improving N relocation to the grain by enhancing sink capacity.

Belda et al. (1992) studied the mineral nutrition of wheat organ and crop stage relationship. They reported that fertilizer treatment affected plant dry weight consistently from anthesis onwards, 90 kg N/ha and calcium gave the highest dry weight. Dry matter yield increased by 77 to 172 per cent during anthesis and by 32 to 45 per cent post anthesis depending on site. The leaf dry weight decreased with leaf age and position, between anthesis and post anthesis. The flag leaf dry weight decreased by 23 to 25 per cent. Regression analysis was used to model the relationship between different organ weight in the same or consecutive growth stages. The frequency of highly significant relationship was higher during anthesis and shooting than during tillering, post anthesis and harvesting stages. Plant dry weight was more closely related to the weights of flag leaf and second youngest leaf than third youngest leaf weight. The total plant weight was strongly related to ear and grain weight at post anthesis and harvesting. It was suggested that weight of the youngest leaf at anthesis was a suitable indicator of biomass and could be used as a reference in the relationship between biomass and mineral content expressing the nutritional status of plant.

Chand and Tomar (1992) carried out the experiment to study the effect of farm yard manure (FYM) and availability of phosphorus to wheat in soils of different physiochemical

properties. They reported that the dry matter yield, shoot phosphorus concentration and P uptake by wheat in the control increased with increase in the available P but decreased with increase in CaCO_3 content. The application of P and FYM significantly increased the dry matter yield and the concentration and uptake of P by wheat shoot, but the magnitude of the response varied with the soil manures and P fertilizer supplemented each other. The farmer was more effective in retarding P fixation and at low rate of P application.

2.3 Days required for different growth stages

Donnelly (1984) conducted the experiment on physiological studies related to grain yield in winter wheat and he observed that loss of green colour from all ear parts was the best indicator of the time of maximum grain dry weight in winter wheat. Grains at different position in the ear generally reached maximum dry weight within the same day. Grain yield depends on sources of assimilates other than ear during the final stages of growth, since net ear photosynthesis reached zero prior to maximum grain dry weight. Lower yielding cultivar with lower shoot survival invested more in large shoots which fail to produce ears.

Sibony and Pinthus (1988) studied the floret initiation and development in spring wheat and they reported

that the inter spikelet variation in the total number of initiated florets was rather small. However, the number of florets at advance stage of development, as well as the number of grains was highest in central spikelets in which florets initiated first. The floret initiation did not proceed beyond spike emergence where after the distal florets and the spikelets apex degenerated. The grain set was restricted to florets which developed at least to the stage of visible anther lobe at spike emergence. The number of these florets was increased significantly by nitrogen application.

Bharud and Patil (1989) studied the physiological maturity in wheat. The data obtained for three years indicated that the wheat varieties viz., HD-2189 and NI-5439 attained physiological maturity at 42 and 46 days after anthesis (DAA) respectively, when dry matter accumulation accompanied with germination percentage (minimum 85 %) was maximum under Rahuri condition.

2.4 Growth functions

Radford (1967) summarised the 'Growth Analysis' formula for most common use was derived and all the necessary assumptions involved in their derivation were explained. The dangers of the indiscriminate use of these formula was highlighted and recommendations were given on the selection of appropriate ones in a given situation. A distinction was made

between the traditional technique which involves the calculation of mean growth rates etc Over time periods and alternative approach which enables a continuous trace of change with time to be made

Flood and Haliloran (1986) observed that there were no differences in net assimilation rate (NAR) between the four lines until 40 days from sowing and there after it decreased, with the greatest decrease in the line with the strongest vernalization response

Bali et al. (1991) studied the yield behaviour and various physio-agronomic characters of wheat and tritple genotype as influence by nitrogen fertilization under the temperate conditions of Kashmir and they indicated that the net assimilation rate (NAR) which was in triticle attained maximum values at the ear emergence phase

2 5 Post harvest studies

Singh and Stoskopf (1971) reported that a high degree of variability was found in the harvest index of winter wheat and other cereals Stem contributed the greatest amount of dry weight to the straw yield and thus, as a vegetative part, materially influence the harvest index The reduction in plant height had a great effect on the stem dry weight and least on grain yield Reduction in plant height lowered the

dry weight of vegetative parts and thereby lower the straw yield which resulted in an increased harvest index. Harvest index was positively correlated with vegetative growth.

Langer and Liew (1973) reported that the spikelet number was increased only by raising nitrogen supply at the double ridge stage

Khalifa (1973) reported that grain yields were unaffected by either source of nitrogen or by method of application. Addition of fertilizers in early phase of growth of crop (at sowing or tillering) gave the greatest response. Significant response of high yielding varieties of wheat to nitrogen upto 180 kg N/ha with positive interactions have been reported by Shukla et al (1979)

Naphade and Bhojar (1975) studied the effect of continuous application of FYM with and without fertilizers on the fertility status of the soil and yield of wheat. They reported that combined use of fertilizers with the application of 5 cart loads per acre of FYM appeared to be more effective in increasing the grain yield of wheat

Nagre and Bathkal (1978) reported that application of 120 kg N + 60 kg P_2O_5 per hectare recorded the highest and significantly more yield of wheat crop than 90 kg N + 45 kg P_2O_5 per hectare and 60 kg N + 30 kg P_2O_5 per hectare. Full

dose of fertilizer in combination of eight irrigations recorded the maximum yield

Sharma and Das (1982) studied the response of wheat to application of Zinc, Boron and Molybdenum. The result obtained revealed that among the nutrients the effect of zinc was significant, zinc application @ 17.50 kg/ha in November sowing was expected to give maximum grain yield whereas, maximum net profit was expected at 10.7 kg Zn/ha and between the sowing dates November 15 was superior to December 15.

Nagre et al (1982) reported that grain yield of wheat increases with increase in level of nitrogen upto 120 kg N/ha. Interaction between varieties and nitrogen levels was also significant. At lower fertility level of 40 kg N/ha, CC-464 produced significantly more yield (30.2 q/ha) than Kalyansona (25.7 q/ha), while at moderate fertility level 80 kg N/ha there were no significant differences between CC-464, Kalyansona and HD-4502. At higher fertility level of 120 kg N/ha, both CC-464 (35.4 q/ha) and Kalyansona (34.9 q/ha) produced significantly higher yield over HD-4502 (31.3 q/ha).

Nagre (1983) conducted the trial at Akola (M.S.) and he reported that application of 120 kg N/ha was at par with 80 kg N/ha and both recorded significantly more yield than 40 kg N/ha. Interaction between varieties and nitrogen

level was significant. Kalyansona responded to nitrogen application upto 120 kg N/ha whereas CC-464 and HD-2189 responded to nitrogen upto 80 kg N/ha

Bhaliya et al. (1983) stated that application of nitrogen at 120 kg N/ha recorded grain yield (31.7 q/ha) as high as that of higher level of 160 kg N/ha (33.2 q/ha). Favourable effects on yield attributes viz., productive tillers per unit area, ear length, spikelets per ear, grains per ear and test weight under this level might have been responsible for higher grain yield. Relative consistency in grain yield with an increase in nitrogen level from 120 to 160 kg N/ha indicated that application of nitrogen greater than 120 kg N/ha not required for harvesting potential yield of wheat and emerge out to be optimum dose.

Singh et al. (1984) conducted a field experiment to study the nitrophosphate of different water solubilities and triple super phosphate as a source of phosphorus on wheat. Marked increase in grain yield was obtained upto 60 kg P_2O_5 /ha. Nitrophosphate having 80 per cent water soluble P as well as triple phosphate gave almost equal yield. Like yield, uptake of nutrient was higher in triple super phosphate and nitrophosphate (80 % water soluble P).

Reddy and Bharadwaj (1984) studied the effect of nitrogen and phosphorus on growth and yield of wheat

Nitrogen increased grain and straw yield and all yield attributes except 1000 grain weight which was decreased. Successive increment of nitrogen upto 80 kg/ha increased grain yield significantly. The differences between 80 and 120 kg N/ha were significant and phosphorus application increased the number of ears, ear weight, fertility ratio of spikelets, 1000 grain weight, grain and straw yield.

Pandurangi et al (1984) conducted a field experiment to study the effect of different levels of nitrogen fertilization on the yield, protein and amino acid composition of wheat grain. Nitrogen fertilization upto 100 kg nitrogen per hectare had beneficial effects on grain yield, protein and amino acid content. However, higher level of nitrogen fertilization had adverse effect, except lysine, all amino acids were positively correlated with protein.

Auti and Kenjale (1985) reported that the reduction in dose of N and P_2O_5 to late sown wheat grown after heavily fertilized sugarcane did not help in economising their use and normal dose of 100 kg + 50 kg P_2O_5 produced significantly more grain yield. However, in case of late January sowing, the fertilizer doses did not produce significantly different grain yield suggesting that for late January sowing 60 kg N and 30 kg P_2O_5 /ha was sufficient.

Pawar et al (1988) reported that the trials conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri (M S) for two years indicated that the yield of wheat was drastically reduced when fertilizer dose was reduced to 50 per cent of the recommended level

Soni et al (1988) conducted the experiment on large term effects of fertilizer application on productivity in rice, wheat sequence and they reported that there was very little scope of reducing or skipping any amount of nitrogen, phosphorus and potassium either for rice crop or wheat. The continuous application of these major nutrients to the crops at recommended level of 120 kg N + 80 kg P₂O₅ + 40 kg K₂O/ha could sustain high yield and maintain soil fertility

Soni et al (1989) studied the response of dwarf wheat to seed rate and nitrogen under limited irrigations and they reported that nitrogen application influenced significantly grain and straw yield. Highest grain yield of 29.09 q/ha was recorded when crop was fertilized with 125 kg N/ha increasing the grain yield by 78.6, 37.0 and 16.2 per cent over control, 75 and 100 kg N/ha, respectively

Nakhtore and Kewat (1989) conducted the experiment to study the response of dwarf wheat to varying fertility levels under limited and adequate irrigation conditions and they concluded that grain and straw yield increased

significantly with increase in fertility levels from zero (13.2 q/ha) to 100 per cent of recommended dose of 120 kg N + 60 kg P₂O₅ + 40 kg K₂O/ha (37.2 q/ha). The increase in grains yield could be attributed to its significant effect on yield components. Significant variation in protein content was noted among different fertility levels.

Giorgio et al (1989) studied the influence of residual fertility and increasing nitrogen rates on physiological and morphological components of durum wheat quality and yield. They reported that the number of spikelets/spike was the greatest with 90 kg N, while the number of grains/spike was the greatest with 80 kg N. Grain protein content and N content were greater after legume than after grass crop and increased up to 120 kg N. Grain N uptake was greater with preceding legume than with preceding grass crop up to N rate of 90 kg N.

Dhuka et al (1991) studied the response of irrigated late sown wheat to nitrogen application and they reported that the grain and straw yield at 80 and 120 kg N/ha were similar but significantly superior over 40 kg N/ha. Plant height, length of spike, spikelets/spike and grains/spike were also significantly increased by N application. The net return at 80 and 120 kg N/ha were also higher. The N applied as 1/2 basal + 1/4 top dressed 21 DAS +

1/4 top dressed 35-40 DAS gives significantly higher grain yield (22.59 q/ha) over all other modes of N application. Length of spike, spikelets/spike, grains/spike, straw yield and net return (Rs 4183/ha) were also significantly higher with this mode of N application. The lowest grain and straw yield were obtained when all N was applied as a basal at the time of sowing. This might be due to loss of applied N through leaching with successive irrigations at earlier growth stage. Similar results were also reported by Padmon₁ et al (1976), hence they concluded that late sown wheat can be grown with 80 kg N/ha applied 1/2 basal + 1/4 top dress 21 DAS + 1/4 top dress 35-40 DAS in loamy sandy soils for getting highest returns.

Hadzic (1991) studied the rational application of fertilizers to winter wheat and they reported that average yield were highest (6.7 t grains/ha) with 40 kg N + 80 kg P₂O₅ + 80 kg K₂O/ha applied before sowing, 60 kg N + 30 kg P₂O₅ + 30 kg K₂O/ha at tillering and 60 kg N/ha as calcium ammonium nitrate at stem elongation.

Upadhyaya and Dubey (1991) studied the response of wheat genotypes to varying fertility levels under limited and adequate water supply and they concluded that grain yield was highest with 4 irrigations and 120 kg N + 60 kg P₂O₅ + 40 kg

K₂O (3 53 and 3 80 t/ha in 1987-88 and 1988-89, respectively)
HD-2236 gave the highest grain yield and 1000 grain weight

Chauhan and Ram (1993) studied the response of wheat to different fertility levels under partially reclaimed salt affected soil and they summarised that the maximum yield of grain and straw was obtained with the application of 120 kg N + 60 kg P₂O₅. It indicated that additional amount of nitrogen and phosphorus was not necessary for the better production of wheat under partially reclaimed sodic soil. The yield increased significantly over control upto normal level of fertilizer application and declined thereafter. The decrease in yield at fertility level (N₁₈₀ P₉₀) may be ascribed to accumulation of NO₂ in soil to toxic level and NO₃ in plant. Beside nitrogen, accumulation of phosphorus in plant at higher level of P₂O₅ also had toxic effect on yield. They concluded that normal level of fertility (N₁₂₀ P₆₀) gave maximum production of wheat under partially reclaimed sodic soil and hence high level of fertility should be avoided.

Sharma and Sharma (1993) carried out the experiment to know the fertility management for yield maximization of Rice-wheat cropping system and they reported that grain yield of rice of manured plots increased by 11.5 to 22.5 q/ha with increase the fertilizer level from 50 to 100 and 150 kg/ha, respectively as compared to 10.8 and 18.2 q/ha in unmanured

plots Corresponding increase in wheat yield was 12.3 and 18.4 q/ha in manured and 10.1 and 16.2 q/ha in unmanured plots Closer the planting of rice seedling at 15 x 15 cm spacing and cross sowing of wheat significantly out yielded the lower populations Combined use of FYM and 150 per cent NPK with increased plant population helped in pushing up the maximum yield level from 112 to 129 q/ha/year due to an appreciable improvement in the soil fertility status Application of FYM + 50 or 100 per cent NPK gave statistically same yield as 100 or 150 per cent NPK, respectively in both the crops.

Verma (1994) studied the balance fertilization of wheat in Eastern India He concluded that the balance use of NPK fertilizer in the ratio of 4:2:1 can accelerate the efficiency of applied nutrients in augmenting the productivity of wheat The use of 100 per cent recommended dose of NPK with FYM enhanced the productivity of wheat crop Need based liming of acidic soils not only restores yield stability but also improves productivity

2.6 Quality aspects

Abrol et al. (1971) showed that enhanced protein content observed following increase in fertilizer application was mainly accounted for by an increase in gluten content Bran and Shorts (middings) have a higher percentage of protein

than flour. However accumulation at high fertility takes place in flour only.

McNeal et al (1972) stated that grain and plant nitrogen help to determine the nature of the expression of grain nitrogen content in spring wheat. Grain nitrogen was negatively related to grain yield and the grain straw ratio. The differences in plant growth characteristic among the eight crosses seems to be account for the difference in grain nitrogen content.

Hunter and Stanford (1973) observed that the protein contents were increased from 10.9 per cent with no nitrogen to 14.3 per cent with nitrogen fertilizer. The optimum rate of nitrogen for maximum grain yield often resulted in higher protein content than was considered desirable in grain used for pastry making. The importance of soil nitrogen as a source of nitrogen in these experiments was illustrated by the significant correlation that existed between relative nitrogen mineralization rate of soils from zero nitrogen plots and corresponding protein yields.

Attarde and Khuspe (1979) suggested that the protein and gluten content were more in NI-917 and NI-747-19 than the Mexican varieties viz., Kalyansona and Sonalika. The protein and gluten contents were increased with increase in the levels of nitrogen from 80 to 160 kg/ha.

Badhe and Mundwaik (1982) concluded that mobility of the elements particularly iron and zinc is restricted as a result of their antagonistic relationship with phosphorus or due to physiological inhibition caused by the higher concentration of phosphorus in the above ground portion of the crops

Evans (1983) concluded that the rate of CO_2 assimilation was uniquely related to the total leaf nitrogen irrespective of nutrient treatment, season and leaf age. Assimilation rate increased with leaf nitrogen, but the slope of relationship declined markedly. When leaf nitrogen exceeded 125 millimoles nitrogen per square metre

Batten (1986) studied the uptake and utilization of phosphorus and nitrogen by Diploid, tetraploid and hexaploid wheats (T spp) and he observed that phosphorus efficiency (PE) was considered in term of yield/unit of P in the main shoot and concentration of phosphorus in grain (% P). In low P set, PE which ranged from 110 to 715 mg grain mg^{-1} P, increased as the yield/clum and dry matter partitioning (HI) increased. Grain phosphorus was highly negatively correlated with the log of grain yield ($r = -0.74, -0.88$) and the log of harvest index ($r = -0.80$ and -0.88) for control and 1 respectively. This suggested that future grain harvest index will cause smaller reduction



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phosphorus concentrations. But within either a high or low phosphorus supply, wheat with a given grain harvest index have significantly different grain phosphorus concentrations and conscious selection for this character was feasible

Jadhav and Koregave (1988) studied the effect of N, P₂O₅ fertilizers on nitrogen and phosphorus uptake and quality of wheat under sequence cropping and they observed that the N and P uptake, protein content in wheat grain and straw, protein production were increased significantly when wheat was grown after groundnut than after sorghum. A protein content in wheat grain and straw was also increased significantly with successive delay in wheat sowing. However, N, P uptake and protein production was decreased significantly under delayed sown wheat. The N and P uptake, protein content in wheat grain and straw, protein production were increased significantly with increase in the level of fertilizers and pooled N and P uptake

HE et al. (1990) studied the protein content of durum wheat varieties in relation to ecological environment. They reported that protein content was positively correlated with daily average temperature during grain filling and was negatively correlated with growth period, number of days to grain filling and 1000 grain weight. Six varieties had a protein content averaging 18 per cent over all sites.

Muller et al (1991) observed that grain nitrogen uptake was greatest when no tillers were removed. Number and weight of grains/spike decreased as the number of fertile stem/plot increased from 10 to 47 and 1000 grain weight decreased from 55.0 to 42.5 g.

Cervato and Piva (1991) studied the nitrogen fertilizer application on wheat (*T. aestivum* L.) Uptake and distribution of nitrogen in organ of plant and summarised the nitrogen distribution between plant parts did not differ between fertilizer treatments. When the first node was visible, about 70 per cent of plant nitrogen was in the leaves and the remainder in the stem. At anthesis, about 40 per cent nitrogen was in leaves, 40 per cent N in stem and 20 per cent N in spikes. At maturity about 75 per cent of nitrogen was in spikes, 15 per cent in stem and 10 per cent in leaves.

Tormanova et al (1991) observed the inter relationship of nitrogen status and growth of winter wheat plant under condition of hardening and NO_3 or NH_4 and they concluded that the effect of nitrogen source and temperate conditions on dry matter and nitrogen accumulation varied in leaves, stem and roots of 2 cultivars. The uptake, accumulation and utilization of nitrogen for growth and the degree of involvement of different organs in assimilation depend on nitrogen forms and cultivars.

Patil and Pal (1991) studied the N, P and K relationship in wheat at various stages of growth and they reported that N content of plant decreased gradually from 30 to 90 DAS and was greater than four times higher in grain than the straw. There was a weak positive correlation between nitrogen content and yield at 30 DAS and strong positive correlation at 60 days and harvest. Phosphorus content decreased upto 90 DAS and was 3 times greater in the grain than the straw. P content was positively but weakly correlated with yield upto 60 DAS after which it showed a negative correlation. K content decreased upto 90 DAS and was four times greater in the straw than the grain. K content was weakly positive correlated with yield upto 60 DAS. The correlation was greater at 90 DAS.

Chapter Opener Page

*Material
& Methods*

3. MATERIAL AND METHODS

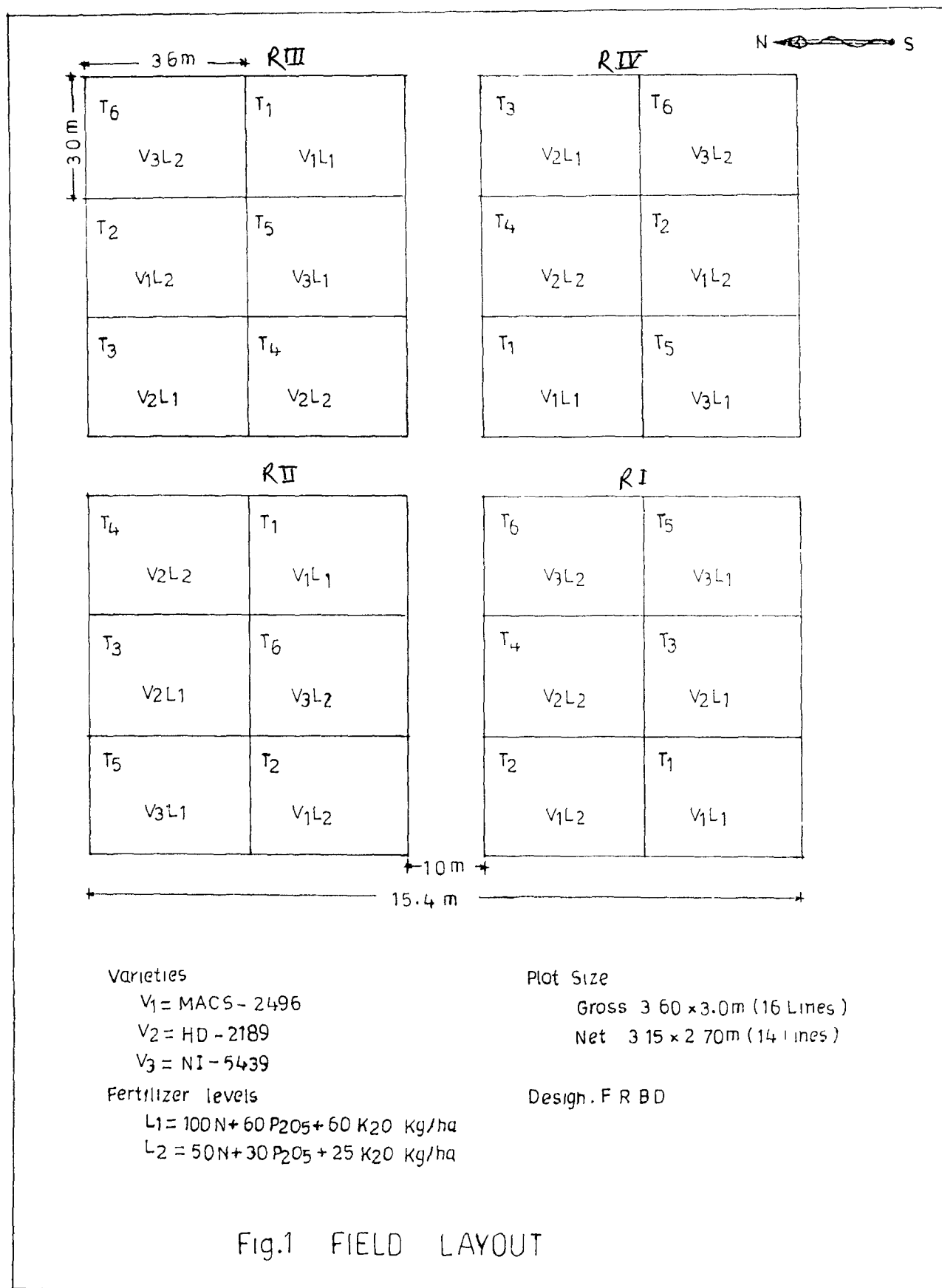
A field trial on the "Physiological analysis of growth and yield of wheat as influenced by fertility levels", was conducted during rabī season of 1993-94 at Post Graduate Research Farm, Department of Botany, Central Campus, Mahatma Phule Krishi Vidyapeeth, Rahurī (Maharashtra State). The details of materials used and the methods followed in conducting the field experiment are described in this chapter.

3.1 Preparation of field

A piece of fairly well levelled land and with uniform fertility level was selected for conducting the experiment. Before laying out the experiment, field was first ploughed and harrowed twice to bring the soil to fine tilth and then stubbles, weeds and debris of previous crop were removed. The experiment was laid out in a Factorial Randomised Block Design with 3.60 x 3.0 meters gross plot size and 3.15 x 2.70 meters net plot size and replicated four times. The soil of the experiment field was well drained. The soil was clayey, low in available nitrogen, medium in phosphorus and high in available potash.

3.2 Treatment details

In present investigation, three wheat varieties were used viz., MACS-2496 (V_1), HD-2189 (V_2) and NI-5439 (V_3). These are high yielding varieties and responsive to management practices as well as fertilizers. The following fertilizer doses were applied.



Total - L₁ - 100 N + 60 P₂O₅ + 60 K₂O kg/ha
 L₂ - 50 N + 30 P₂O₅ + 25 K₂O kg/ha
 Basal - L₁ - 50 N + 60 P₂O₅ + 60 K₂O kg/ha
 L₂ - 25 N + 30 P₂O₅ + 25 K₂O kg/ha
 Top dressing - L₁ - 50 kg N/ha - 30 DAS
 L₂ - 25 kg N/ha - 30 DAS

Thus, there were six treatment combinations as detailed below

| Varieties | Fertilizer doses | |
|-----------|-------------------------------|-------------------------------|
| | 100.60 60 (NPK kg/ha) | 50.30 25 (NPK kg/ha) |
| MACS-2496 | V ₁ L ₁ | V ₁ L ₂ |
| HD-2189 | V ₂ L ₁ | V ₂ L ₂ |
| NI-5439 | V ₃ L ₁ | V ₃ L ₂ |

3 3 Seed and sowing

The pure seeds of above three varieties were obtained from wheat specialist, Agricultural Research Station, Niphad (Nasik). The germination test was carried out before sowing. The seed treatment was carried with Agrosan G.N @ 2.5 gm/kg seed before sowing

The experimental plot was irrigated before sowing and after wafsa condition, the plot was prepared for sowing. The sowing was done in line by drilling 22.5 cms between the rows. The sowing was done on 11 November, 1993

3.4 Fertilizers and after care

At the time of sowing, plots were fertilized at the rate of 50 kg N, 60 kg P_2O_5 and 60 kg K_2O per hectare for first level of fertilizer and 25 kg N, 30 kg P_2O_5 and 25 kg K_2O per hectare for second level of fertilizer in the form of suphals and murate of potash. Full dose of P_2O_5 and K_2O and half dose of nitrogen was applied at the time of sowing as a basal dose. The remaining half of the nitrogen was applied 30 days after sowing as a top dressing in the form of urea. Throughout the experiment, the plots were irrigated five times. First interculturing was done at 21 DAS and subsequent interculturings were done as and when required, and the experimental area was kept clean throughout the experimentation.

3.5 Growth observations

Following observations were recorded at 30, 45, 60 and 75 days after sowing.

3.5.1 Mean plant height

The total height of main shoot of the observational plants was recorded in cms from the ground level to the base of the last fully opened leaf upto the stage of earhead emergence. After this period, main shoot height was measured from ground level upto the base of earhead.

3 5 2 Mean number of tillers per plant

The number of tillers per plant was recorded periodically

3 5.3 Mean leaf area per plant

For determination of the leaf area, the plants were sampled and the leaves and stem were separated. The separated leaves were immediately used for measuring the leaf area with the help of Automatic leaf area measuring meter and the leaf area was recorded

3 5 4 Mean leaf area index (LAI)

The leaf area index represents the ratio of leaf area to land area available for the plant, expressed in the same units. LAI per unit area was worked out by using formula given by Watson (1947).

$$\text{LAI} = \frac{\text{Leaf area in cm}^2}{\text{Land area in cm}^2}$$

3 5.5 Mean leaf area duration (LAD)

Leaf area duration was worked out by using the formula suggested by Watson (1947)

$$\text{LAD} = \frac{\text{LAI}_1 + \text{LAI}_2}{2} \times (t_2 - t_1)$$

Where LAI_1 and LAI_2 are the leaf area index at time t_1 and t_2 , respectively

3.6 Dry matter studies

In order to study the dry matter production and accumulation, plant samples were collected at different intervals i.e 30, 45, 60 and 70 DAS

3.6 1 Mean weight of leaves per plant.

At each sampling, five plants were sampled randomly and from these plants the leaves were separated and then collected in brown paper bag and the brown paper bags were dried in hot air oven regulated at 90°C for first one hour and then at constant temperature at 60°C till the samples were completely dried. After drying the sample dry weight of leaves was recorded.

3 6 2 Mean dry weight of stem per plant

The stems of the above sampled five plants were collected in brown paper bags and kept in hot air oven separately and drying of the samples was carried out. After drying, the dry weight of stem per plant was recorded separately

3 6 3 Mean dry weight of ears per plant

Five plants were collected from the field randomly, removed the ears of each plant separately and kept in a hot air oven for drying. After drying, the dry weight of ears were recorded separately of each plant

3 6 4 Mean total dry weight per plant

The addition of above mentioned plant parts i.e. leaves, stem and ears was carried out and the total dry matter per plant was estimated

3 7 Days required for phenological stages

3 7 1 Mean days required for initiation of headings

The date on which first earhead was appeared on the plant, it was recorded and the data were collected for each plot

3.7.2 Mean days required for 50 per cent flowering

When nearly 50 per cent of plants from each plot showed earheads, the data was recorded for each plot and then data were computed

3 7 3 Mean days required for physiological maturity

When complete plant indicating yellowing of leaves stem and earhead This stage of the crop was taken as physiological maturity and data were recorded

3 8 Growth functions

From the data collected on total dry weight per plant at different intervals were used for calculating the absolute growth rate (AGR) and relative growth rate (RGR) The net assimilation rate (NAR) was estimated with the help of total dry weights and leaf area of the plants

3.8.1 Absolute growth rate (AGR)

The absolute growth rate was calculated by formula given by Briggs et al (1920) and expressed as g/day.

$$\text{AGR} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_2 and W_1 are dry matter per plant at the times t_2 and t_1 , respectively.

3.8.2 Relative growth rate (RGR)

Blackman (1919) considered the increase in dry weight of plant as a process of continuous compound interest, where in the increment at intervals adds to the capital for the subsequent growth. This rate of increment is called as RGR and was calculated from the formula given by Briggs et al (1920-21) and expressed as g/g/day

$$\text{RGR} = \frac{\log_e W_2 - \log_e W_1}{(t_2 - t_1)}$$

Where, W_2 and W_1 represent the total dry matter of plant at times t_2 and t_1 , respectively

3.8.3 Net assimilation rate (NAR)

The NAR represents the photosynthetic efficiency of leaves. The relationship between leaf area and dry matter accumulation is measured with the help of NAR by formula suggested by Gregory (1926) expressed as $\text{g/dm}^2/\text{day}$.

$$\text{NAR} = \frac{(W_2 - W_1)}{(L_2 - L_1)} \times \frac{(\log_e L_2 - \log_e L_1)}{(t_2 - t_1)}$$

Where, W_2 and W_1 are total dry matter, L_2 and L_1 denote leaf area per unit area at times t_2 and t_1 , respectively

3.9 Post harvest studies

The post harvest observations were recorded on the observational plants after harvest for main shoot and tillers separately from each plot and following observations were recorded

3.9.1 Number of productive tillers per plant

Five randomly selected plants were harvested separately and number of productive tillers was counted and recorded

3.9.2 Total numbers of ears per plant (main shoot and tillers)

After harvest of the five plants from each experimental plot and counted the main shoot ears and ears on the other tillers separately and addition of these both the ears are total number of ears per plant

3.9.3 Total number of spikelets per ear

The number of spikelets per ear of main shoot and tillers was counted separately

3 9 4 **Number of grains per ear**

The grains were separated from ears of the observational plants and counted and recorded separately from main shoot, tillers and per plant

3 9 5 **Grains weight per ear (main shoot and tillers per plant)**

The grain weight per ear of observational plants was recorded separately from main shoot, tillers and per plant

3 9 6 **Thousand grain weight**

The thousand grain weight per plant of main shoot and tillers of observational plants was recorded separately.

3 9 7 **Yield per net plot and per hectare**

After harvesting each net plot of the experiment, the earheads were threshed, cleaned and dried in sun for four days and data were recorded for yield of net plot. On the basis of net plot yield, the data on yield per hectare was calculated and recorded

3.9 8 **Total biomass per net plot**

The data on total biomass per plant were recorded after complete drying of plants

3 9 9 Harvest index

The harvest index was calculated by the following formula

$$H I = \frac{\text{Grain dry weight (Economical yield)}}{\text{Total dry weight at harvest (Biological yield)}} \times 100$$

3.10 Chemical analysis of plant

The five observational plants at the time of harvest were utilized for chemical analysis. The plant parts i.e. stem, leaves and grains were dried and powdered in the grinding mill separately and then same were stored in plastic bags for further determination of chemical content.

A known quantity (0.2 g) of sample was digested with 1.1 concentrated N-free H_2SO_4 and H_2O_2 (30 %) mixture (Parkinson and Allen, 1975). The acid extract was diluted to 100 ml with distilled water and used for determination of N, P and K separately from stem, leaves and grains (Nelson and Sommers, 1973).

3 10.1 Nitrogen content

The total nitrogen content in plant parts was estimated by modified standard micro-Kjeldahl's method (A O A C , 1975)

3 10 2 Phosphorus content

The phosphorus content in stem, leaves and grains were determined by Nitrovanomolybdate method (Koeing and Johnson, 1942). Readings were taken on Spectronic-20 using blue tiller (415 nm) From these readings and a regression curve percentage of phosphorus was determined

3 10.3 Potassium content

The total potassium was estimated by diluting the acid extract with distilled water and taken the readings on flame photometer method (Hanway and Heidal, 1967)

3.10.4 Protein content of stem, leaves and grains at harvest

From the data on nitrogen content in stem, leaves and grains, the protein content was calculated by multiplying the per cent nitrogen by 6.25

3 11 Soil analysis

In order to study the chemical properties of soil, the soil samples from 0-30 cm layer were taken at random over experimental plot area before sowing After thorough mixing of these samples a composite sample was drawn by quadrant method and soil was analysed After harvest of crop, soil samples were taken from each plot as described above and the soil samples were analysed

3.11.1 Nitrogen

The available nitrogen was estimated by Kjeldahl's method with Bal's modification. Soil was allowed to stand with water before digestion for half an hour (Piper, 1966)

3.12.2 Available phosphorus

This was estimated by Olsen's method (Olsen et al., 1954). The phosphorus was determined calorimetrically by comparing the stannous reduced molybdo phosphoric blue colour using 660 nm filter

3.11.3 Available potassium

Available potassium was extracted by neutral normal ammonium acetate solution the filtrate was treated with two drops of Butyl alcohol and potash was determined by Flame photometer

3.12 Statistical analysis

The data were subjected to statistical analysis using Factorial Randomised Block Design for Analysis of variance. Standard error (SE) of mean was worked out for each factor and critical difference (C.D.) at 5 per cent level of significance was worked out. Wherever, the results were significant, interactions were means presented. The data were suitably illustrated with graphs and figures at appropriate places

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Results

4 . EXPERIMENTAL RESULTS

An experiment on "Physiological analysis of growth and yield of wheat as influenced by fertility levels" was conducted during Rabi 1993-94 at Instructional Farm, Department of Botany, Mahatma Phule Krishi Vidyapeeth, Rahuri. The results obtained are described in this chapter.

4 1 Growth studies

The experimental data on growth includes observations on various growth characters such as plant height of main shoot, number of tillers, leaf area, leaf area index, leaf area duration, etc. The observations were recorded at 15 days interval starting from 30 days after sowing

4.1.1 Mean plant height

The data on mean plant height as affected by different treatments are presented in Table 1 and graphically shown in Fig 2

The data presented in Table 1 indicates that differences in plant height were statistically significant at all the observational occasions

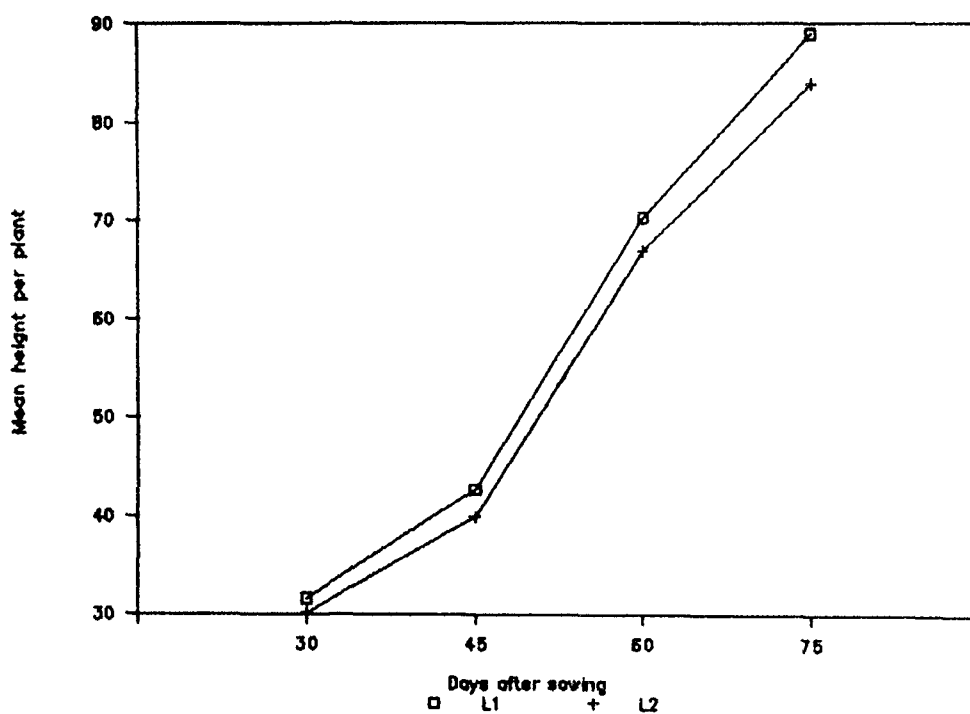
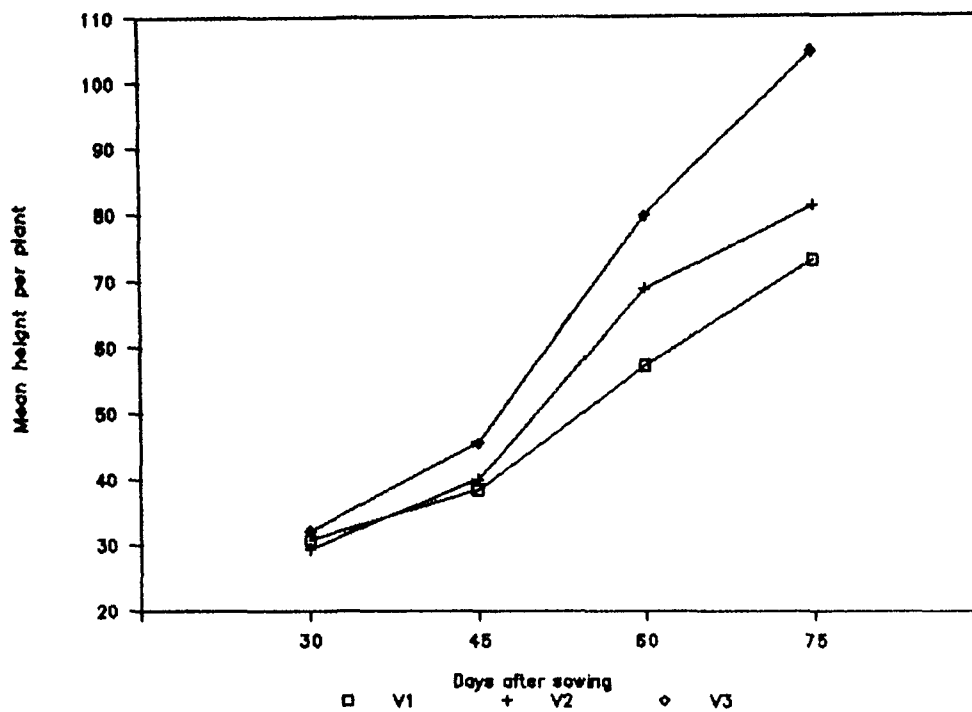
At 30 DAS, the highest plant height was evident under the variety V_3 (NI-5439) which was significantly higher than the variety V_2 (HD-2189). However, the variety V_1 (MACS-2496) was on par with the varieties V_2 and V_3 . The comparison of the fertilizer levels indicated that the fertilizer level

Table 1 : Mean height per plant of main shoot (cm)

| Treatment | Days after sowing | | | |
|----------------------------|-------------------|-------|-------|--------|
| | 30 | 45 | 60 | 75 |
| V ₁ (MACS-2496) | 30.80 | 38.39 | 57.16 | 73.20 |
| V ₂ (HD-2189) | 29.43 | 40.00 | 68.80 | 81.32 |
| V ₃ (NI-5439) | 32.20 | 45.60 | 79.75 | 104.70 |
| S.E. \pm | 0.547 | 1.056 | 1.052 | 1.258 |
| C.D. at 5 % | 1.648 | 3.184 | 3.171 | 3.791 |
| L ₁ | 31.60 | 42.73 | 70.30 | 88.90 |
| L ₂ | 30.10 | 39.90 | 66.90 | 83.90 |
| S.E. \pm | 0.447 | 0.863 | 0.859 | 1.027 |
| C.D. at 5 % | 1.346 | 2.599 | 2.589 | 3.095 |
| Interaction (V \times L) | | | | |
| S.E. \pm | 0.773 | 1.494 | 1.488 | 1.779 |
| C.D. at 5 % | N.S. | N.S. | N.S. | N.S. |

N.S. = Not significant.

Fig. 2 - Mean height per plant of main shoot (cm)



V₁ - MACS - 2496

V₂ - HD - 2189

V₃ - NI - 5439

L₁ - 100 : 60 : 60 NPK kg/ha

L₂ - 50 : 30 : 25 NPK kg/ha

L₁ had significantly higher plant height than the fertilizer level L₂ at this crop growth stage

Further at 45, 60 and 75 days of crop growth stages, the varietal behaviour was almost same. At these crop growth stages, the ~~Maximum~~ ^{Maximum} plant height was observed in the variety V₃ and it was significantly higher than the varieties V₂ and V₁. The lowest plant height was observed under the variety V₁ at all these crop growth stages and it was significantly inferior than the varieties V₂ and V₃ except at 45 DAS, the varieties V₁ and V₂ were on par with each other.

The comparison of fertilizer levels at these crop growth stages indicated that the fertilizer level L₁ had significantly higher plant height than the fertilizer level L₂

Thus, it can be seen that among the varieties, the variety V₃ had consistently and significantly higher plant height than the varieties V₁ and V₂ at all the observational occasions except at 30 DAS. Similarly the fertilizer level L₁ had consistently and significantly higher plant height than the fertilizer level L₂ at all the crop growth stages.

The interaction effect between varieties and fertilizer levels were not significant.

4.1 2 Mean number of tillers per plant

The tiller number was recorded at the interval of 15 days starting from 30 DAS and the data on mean number of tillers per plant are presented in Table 2 and graphically shown in Fig 3

It is evident from Table 2 that varietal differences in respect of tiller number per plant were statistically significant at 60 DAS and highest number of tillers was observed under variety V_3 which was significantly higher than variety V_2 . However, the variety V_3 was on par with variety V_1 .

Further at 30, 45 and 75 days of crop growth stages, the varietal behaviour was almost same but the differences were not significant. At these crop growth stages numerically highest number of tillers per plant was observed in the variety V_3 .

The comparison of fertilizer levels at all the observational occasions indicated that the fertilizer level L_1 had consistently and significantly higher number of tillers per plant than the fertilizer level L_2 .

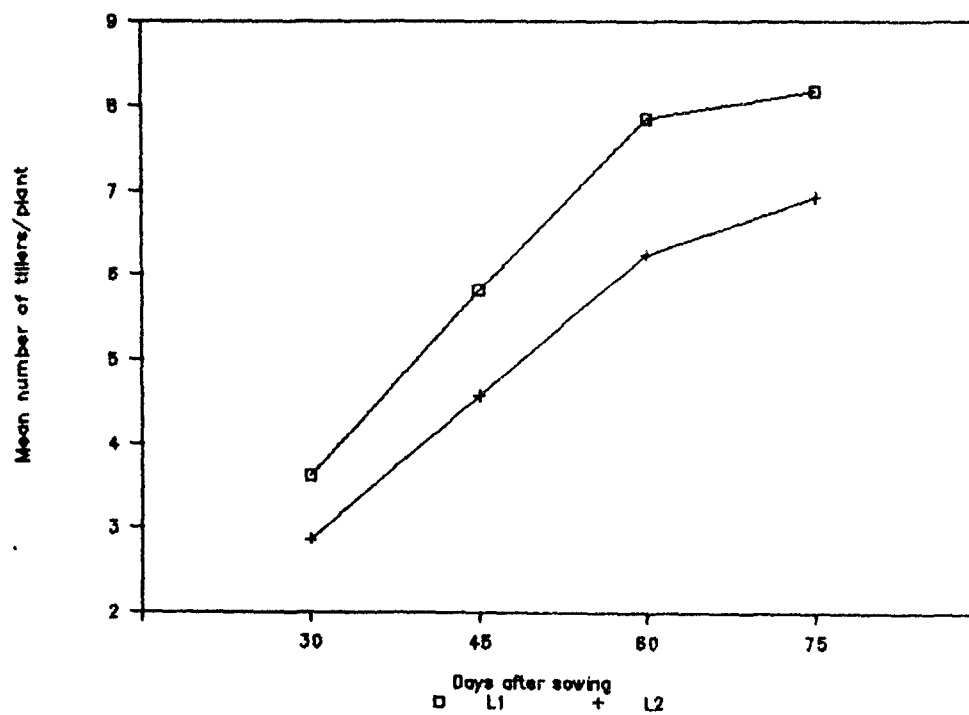
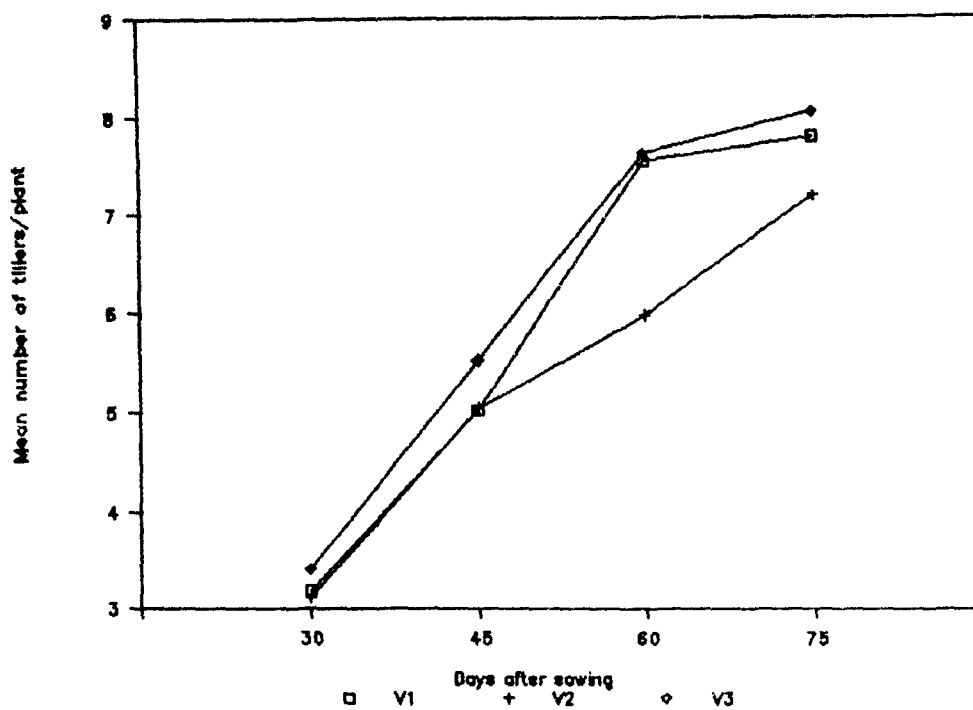
Thus, it can be observed that among the varieties, the variety V_3 had consistently higher number of tillers per plant than the varieties V_1 and V_2 at all the crop growth

Table 2 : Mean number of tillers per plant

| Treatment | Days after sowing | | | |
|----------------------------|-------------------|-------|-------|-------|
| | 30 | 45 | 60 | 75 |
| V ₁ (MACS-2496) | 3.19 | 5.03 | 7.55 | 7.80 |
| V ₂ (HD-2189) | 3.12 | 5.05 | 5.98 | 7.20 |
| V ₃ (NI-5439) | 3.41 | 5.53 | 7.635 | 8.05 |
| S.E. \pm | 0.164 | 0.229 | 0.385 | 0.303 |
| C.D. at 5 % | N.S. | N.S. | 1.161 | N.S. |
| L ₁ | 3.62 | 5.82 | 7.85 | 8.18 |
| L ₂ | 2.87 | 4.58 | 6.250 | 6.92 |
| S.E. \pm | 0.134 | 0.187 | 0.315 | 0.247 |
| C.D. at 5 % | 0.403 | 0.563 | 0.948 | 0.745 |
| Interaction (V \times L) | | | | |
| S.E. \pm | 0.232 | 0.324 | 0.545 | 0.428 |
| C.D. at 5 % | N.S. | N.S. | N.S. | N.S. |

N.S. = Not significant.

Fig. 3 - Mean number of tillers per plant



V₁ - MACS - 2496
 V₂ - HD - 2189
 V₃ - NI - 5439

L₁ - 100 : 60 : 60 NPK Kg/ha
 L₂ - 50 : 30 : 25 NPK kg/ha

stages. Similarly fertilizer level L_1 had consistently and significantly higher number of tillers per plant than the fertilizer level L_2 at all the observational occasions.

The interaction effects between varieties and fertilizer levels were not significant.

4.1.3 Mean leaf area per plant

The mean leaf area per plant of the sampled plants was determined separately at 15 days interval from 30 DAS and the data on mean leaf area per plant are presented in Table 3 and graphically shown in Fig 4.

From Table 3, it can be seen that the differences in mean leaf area per plant of different varieties were statistically significant at 30 and 60 DAS. At 30 DAS the leaf area in the variety V_2 was significantly higher than the varieties V_1 and V_3 . However, the variety V_3 was on par with the variety V_1 . But at 60 DAS, the mean leaf area per plant of variety V_1 was significantly higher than the variety V_2 however, the variety V_1 was on par with the variety V_3 and both these varieties were significantly superior to the variety V_2 .

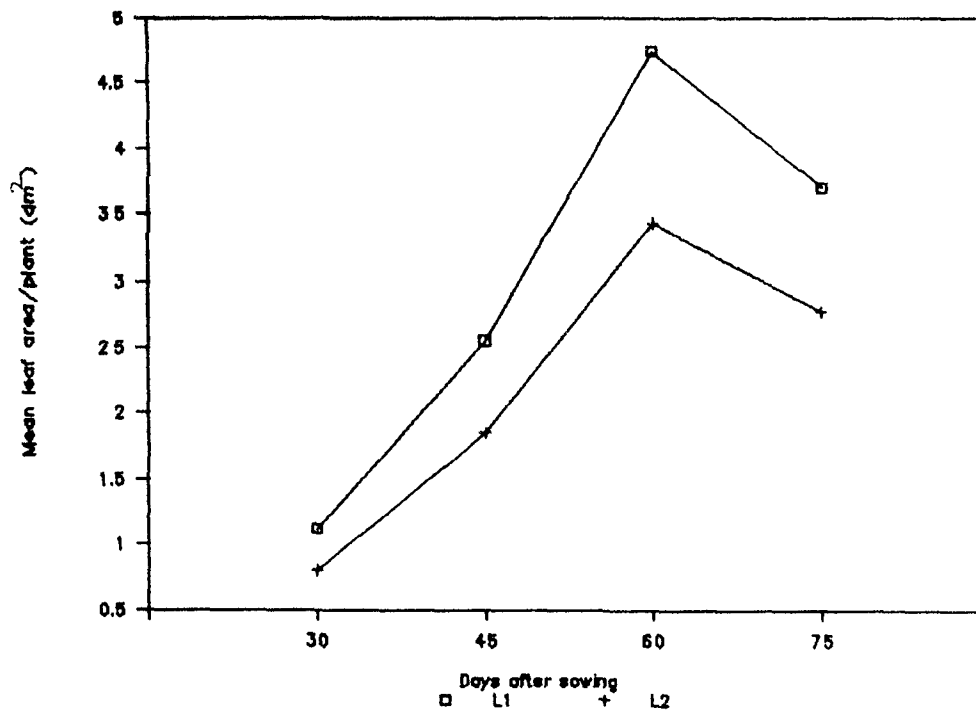
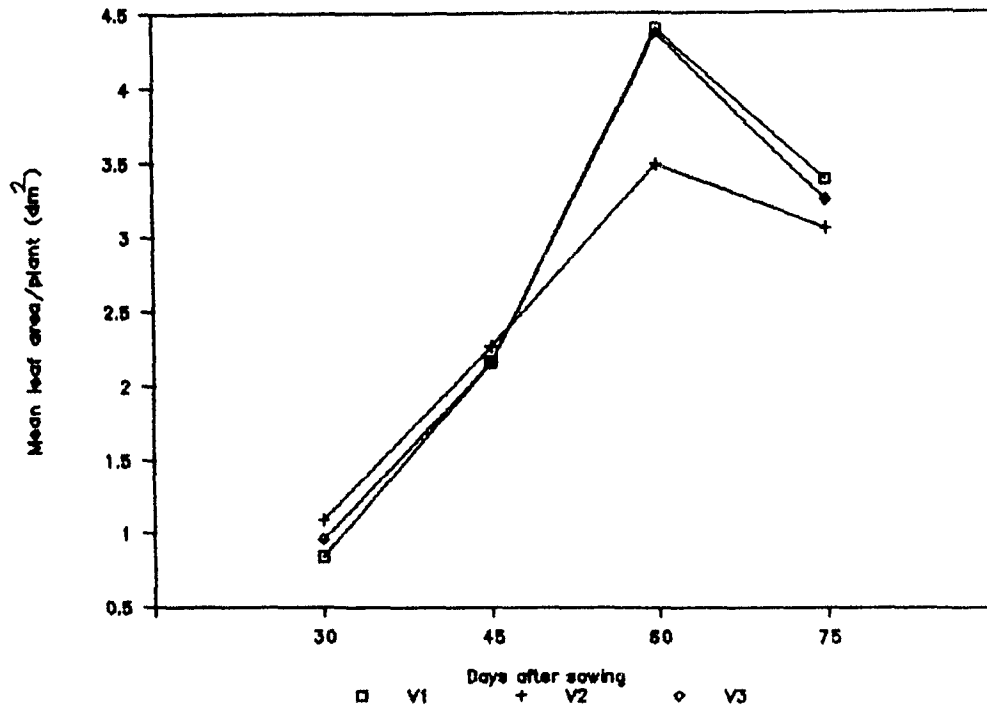
The comparison of fertilizer levels at these crop growth stages indicated that the fertilizer level L_1 was significantly higher for mean leaf area per plant than the fertilizer level L_2 at all the crop growth stages.

Table 3 : Mean leaf area per plant (dm²)

| Treatment | Days after sowing | | | |
|----------------------------|-------------------|-------|-------|-------|
| | 30 | 45 | 60 | 75 |
| V ₁ (MACS-2496) | 0.84 | 2.16 | 4.39 | 3.79 |
| V ₂ (HD-2189) | 1.09 | 2.27 | 3.49 | 3.06 |
| V ₃ (NI-5439) | 0.96 | 2.16 | 4.36 | 3.25 |
| S.E. \pm | 0.041 | 0.108 | 0.247 | 0.145 |
| C.D. at 5 % | 0.124 | N.S. | 0.744 | N.S. |
| L ₁ | 1.12 | 2.55 | 4.74 | 3.70 |
| L ₂ | 0.80 | 1.85 | 3.43 | 2.77 |
| S.E. \pm | 0.034 | 0.088 | 0.202 | 0.119 |
| C.D. at 5 % | 0.101 | 0.266 | 0.608 | 0.357 |
| Interaction (V x L) | | | | |
| S.E. \pm | 0.058 | 0.153 | 0.349 | 0.205 |
| C.D. at 5 % | N.S. | N.S. | N.S. | N.S. |

N.S. = Not significant.

Fig. 4 - Mean leaf area per plant (dm^2)



V₁ - MACS - 2496

L₁ - 100 : 60 : 60 NPK kg/ha

V₂ + HD - 2189

L₂ - 50 : 30 : 25 NPK kg/ha

V₃ - NI - 5439

Thus, it can be seen that the varieties differed in respect of mean leaf area per plant and there was no consistency for the character among the varieties. The fertilizer level L_1 had consistently and significantly higher mean leaf area per plant than the fertilizer level L_2 at all the crop growth stages.

The interaction effects were statistically not significant.

4.1.4 Mean leaf area index (LAI)

The data on mean leaf area index are presented in Table 4. The data presented in Table 4 indicates that the LAI shown the similar trends as that of leaf area.

The varietal differences for leaf area index were statistically significant at 30 and 60 DAS of crop growth stages.

It can be seen from Table 4 that leaf area index increased progressively with advance of time and significantly reached to maximum value at 60 DAS in all the varieties and at 75 DAS the LAI was decreased.

At 30 DAS, the highest leaf area index was observed in the variety V_2 which was significantly higher than the varieties V_3 and V_1 . It was further observed that the variety

Table 4 : Mean leaf area index (LAI)

| Treatment | Days after sowing | | | |
|----------------------------|-------------------|-------|-------|-------|
| | 30 | 45 | 60 | 75 |
| V ₁ (MACS-2496) | 0.37 | 0.96 | 1.95 | 1.51 |
| V ₂ (HD-2189) | 0.49 | 0.99 | 1.55 | 1.36 |
| V ₃ (NI-5439) | 0.43 | 0.96 | 1.94 | 1.45 |
| S.E. \pm | 0.018 | 0.043 | 0.110 | 0.064 |
| C.D. at 5 % | 0.055 | N.S. | 0.332 | N.S. |
| L ₁ | 0.50 | 1.13 | 2.10 | 1.65 |
| L ₂ | 0.36 | 0.81 | 1.52 | 1.23 |
| S.E. \pm | 0.015 | 0.036 | 0.090 | 0.053 |
| C.D. at 5 % | 0.045 | 0.107 | 0.271 | 0.158 |
| Interaction (V \times L) | | | | |
| S.E. \pm | 0.026 | 0.062 | 0.156 | 0.091 |
| C.D. at 5 % | N.S. | N.S. | N.S. | N.S. |

N.S. = Not significant.

V_1 had the lowest mean leaf area index and it was on par with the variety V_3

Further at 60 days of crop growth stage, the highest leaf area index was observed under in the variety V_1 and it was significantly higher than variety V_2 while the lowest leaf area index was evident in the variety V_2 and the varieties V_1 and V_3 were on par with each other

The comparison of fertilizer levels at all the observational occasions indicated that the fertilizer level L_1 was significantly higher than the fertilizer level L_2

The interaction effects between varieties and fertilizer levels were not significant.

4 1 5 Leaf area duration (LAD)

The data regarding mean leaf area duration are presented in Table 5. The varietal differences for mean leaf area duration were statistically significant only at 60 to 75 DAS duration

It can be seen from Table 5 that the mean leaf area duration increased progressively with age of the crop. It was observed that lowest mean leaf area duration was evident in the variety V_2 at 60 to 75 DAS duration and it was significantly inferior than the varieties V_1 and V_3 . While the higher mean leaf area duration was noted under the variety

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Table 5 : Mean leaf area duration

| Treatment | Days after sowing | | |
|----------------------------|-------------------|-------|-------|
| | 30-45 | 45-60 | 60-75 |
| V ₁ (MACS-2496) | 9.99 | 21.84 | 25.96 |
| V ₂ (HD-2189) | 11.05 | 19.04 | 21.86 |
| V ₃ (NI-5439) | 10.45 | 21.75 | 25.50 |
| S.E. \pm | 0.351 | 0.914 | 0.788 |
| C.D. at 5 % | N.S. | N.S. | 2.375 |
| L ₁ | 12.24 | 24.27 | 28.11 |
| L ₂ | 8.76 | 17.48 | 20.77 |
| S.E. \pm | 0.287 | 0.746 | 0.644 |
| C.D. at 5 % | 0.864 | 2.248 | 1.939 |
| Interaction (V x L) | | | |
| S.E. \pm | 0.497 | 1.292 | 1.115 |
| C.D. at 5 % | N.S. | N.S. | N.S. |

N.S. = Not significant.

V_1 and it was statistically on par with the variety V_3 and both these varieties were significantly superior than the variety V_2

The fertilizer levels influenced the mean leaf area duration and with increase in fertilizer level, there was significant increase in mean leaf area duration throughout the sampling period and reached maximum in between 60 to 70 DAS. Thus, the fertilizer level I_1 has consistently and significantly higher LAD than the fertilizer level I_2 at all the sampling occasions.

The varieties x fertilizer level interactions were statistically not significant at all the sampling occasions.

4.2 Dry matter studies

The plant samples were collected at 15 days interval from 30 to 75 DAS and data on dry matter of stem, leaves and ears are presented separately.

4.2.1 Mean dry weight of leaves per plant

The data on mean dry weight of leaves per plant are presented in Table 6.

The data presented in Table 6 indicated that varietal differences for mean dry weight of leaves per plant were statistically significant at 75 days of crop growth stage.

Table 6 : Mean dry weight of leaves per plant (g)

| Treatment | Days after sowing | | | |
|----------------------------|-------------------|-------|-------|-------|
| | 30 | 45 | 60 | 75 |
| V ₁ (MACS-7496) | 0.48 | 0.86 | 2.40 | 2.34 |
| V ₂ (HD-2189) | 0.49 | 0.94 | 2.25 | 2.54 |
| V ₃ (NI-5439) | 0.49 | 0.90 | 2.58 | 1.86 |
| S.E. \pm | 0.035 | 0.036 | 0.181 | 0.137 |
| C.D. at 5 % | N.S. | N.S. | N.S. | 0.414 |
| L ₁ | 0.56 | 0.98 | 2.84 | 2.63 |
| L ₂ | 0.41 | 0.81 | 1.98 | 1.86 |
| S.E. \pm | 0.029 | 0.030 | 0.148 | 0.112 |
| C.D. at 5 % | 0.087 | 0.090 | 0.445 | 0.338 |
| Interaction (V \times L) | | | | |
| S.E. \pm | 0.050 | 0.051 | 0.256 | 0.194 |
| C.D. at 5 % | N.S. | 0.154 | N.S. | N.S. |

N.S. = Not significant.

only The highest mean dry weight of leaves per plant was evident under the variety V_2 which was significantly higher than the variety V_3 . The varieties V_1 and V_2 were on par with each other and both these varieties were significantly superior over the variety V_3 at this crop growth stage.

The comparison of fertilizer levels at all the observational occasions indicated that the fertilizer level L_1 had significantly higher dry weight of leaves per plant than the fertilizer level L_2 .

Hence it can be seen that among the varieties, variety V_2 had significantly higher mean dry weight of leaves per plant than the variety V_3 at 75 DAS and the fertilizer level L_1 had consistently and significantly higher mean dry weight of leaves per plant than the fertilizer level L_2 at all the crop growth stages.

The interaction effects between varieties and fertilizer levels were found to be significant only at 45 days of the crop growth stage. The data regarding interaction effects are presented in Table 7.

Table 7 Mean dry weight of leaves per plant as affected by V x L interaction at 45 DAS

| Treatment | L ₁ | L ₂ | Mean | S.E.± | C D at 5 % |
|----------------|----------------|----------------|------|-------|------------|
| V ₁ | 0 96 | 0 77 | 0 86 | 0 051 | 0.154 |
| V ₂ | 0 92 | 0 96 | 0 94 | | |
| V ₃ | 1 08 | 0 72 | 0 90 | | |
| Mean | 0 98 | 0 81 | | | |

The interaction effects at 45 DAS, indicated that the treatment combination V₃L₁ had the highest dry weight of leaves which was significantly higher than all treatment combinations except V₁L₁ and V₂L₂. While the lowest mean dry weight of leaves per plant was observed under the treatment combination V₃L₂ which was significantly inferior than all other treatment combinations except V₁L₂.

4 2 2 Mean dry weight of stem per plant

The data regarding mean dry weight of stem per plant are presented in Table 8

It can be seen that dry matter accumulation in the stem was slow upto 45 DAS and thereafter it increased at faster rate. Further, it was observed that at 30 and 60 days of the crop growth stages, the varieties did not differ significantly for mean dry weight of stem per plant. However, at 45 and 75 DAS, the varietal differences were significant.

Table 8 : Mean dry weight of stem per plant (g)

| Treatment | Days after sowing | | | |
|----------------------------|-------------------|-------|-------|-------|
| | 30 | 45 | 60 | 75 |
| V ₁ (MACS-2496) | 0.20 | 0.54 | 2.24 | 2.61 |
| V ₂ (HD-2189) | 0.21 | 0.64 | 2.57 | 2.85 |
| V ₃ (NI-5439) | 0.23 | 0.57 | 2.55 | 3.41 |
| S.E. \pm | 0.013 | 0.026 | 0.128 | 0.126 |
| C.D. at 5 % | N.S. | 0.079 | N.S. | 0.380 |
| L ₁ | 0.25 | 0.61 | 2.77 | 3.23 |
| L ₂ | 0.18 | 0.56 | 2.13 | 2.68 |
| S.E. \pm | 0.011 | 0.021 | 0.104 | 0.103 |
| C.D. at 5 % | 0.033 | N.S. | 0.314 | 0.310 |
| Interaction (V x L) | | | | |
| S.E. \pm | 0.019 | 0.037 | 0.180 | 1.178 |
| C.D. at 5 % | N.S. | 0.112 | N.S. | N.S. |

N.S. = Not significant.

At 45 DAS, the variety V_2 had significantly more mean stem dry weight per plant than the variety V_1 while variety V_1 had lowest stem dry weight per plant and it was on par with the variety V_3

At 75 DAS, the results obtained are some what different wherein the lowest dry weight of stem per plant was recorded under the variety V_1 which was statistically on par with the variety V_2 and both these varieties were significantly inferior to variety V_3

The fertilizer levels showed the pronounced influence on accumulation of stem dry weight per plant. Thus, the fertilizer level L_1 had statistically and significantly more dry weight of stem per plant than the fertilizer level L_2 at all the observational occasions except 45 days of crop growth stage.

Thus, it can be seen that varietal behaviour for dry weight of stem per plant was not consistent at different sampling occasions. Further it was observed that the fertilizer level L_1 has consistently and significantly higher dry matter of stem per plant than the fertilizer level L_2 at all the sampling occasions

The interaction effects between varieties and fertilizer levels were significant at 45 days of crop growth

stage. The data regarding mean stem dry matter per plant as affected by V x L interactions are given in Table 9

Table 9 · Mean stem dry weight per plant in grams as affected by V x L interaction (g)

| Treatment | L ₁ | L ₂ | Mean | S E ± | C D at 5 % |
|----------------|----------------|----------------|------|-------|------------|
| V ₁ | 0 57 | 0 51 | 0 54 | 0 037 | 0 112 |
| V ₂ | 0 58 | 0 71 | 0 64 | | |
| V ₃ | 1.68 | 0 46 | 0 57 | | |
| Mean | 0 61 | 0 56 | | | |

The data presented in Table 9 revealed that the treatment combination V₂L₂ had the highest dry weight of stem per plant and it was significantly higher than all other treatment combinations except V₃L₁. While, the lowest dry weight of stem per plant was observed under the treatment combination V₃L₂ and it was significantly inferior than treatment combinations V₂L₁, V₃L₁ and V₂L₂.

4.2.3 Mean dry weight of earheads per plant

The mean dry weight of earheads was recorded at harvest. The data on mean dry weight of earheads are presented in Table 10.

The data presented in Table 10 revealed that the highest mean dry weight of earheads per plant was evident under the variety V₂ which was significantly superior than

Table 10 : Mean dry weight of earheads per plant (g)

| Treatment | At harvest |
|----------------------------|------------|
| V ₁ (MACS-2496) | 2.67 |
| V ₂ (HD-2189) | 5.13 |
| V ₃ (NJ-5439) | 3.88 |
| S.E. ± | 0.450 |
| C.D. at 5 % | 1.357 |
| L ₁ | 4.76 |
| L ₂ | 2.99 |
| S.E. ± | 0.368 |
| C.D. at 5 % | 1.108 |
| Interaction (V × L) | |
| S.E. ± | 0.637 |
| C.D. at 5 % | N.S. |

N.S. = Not significant.

variety V_1 . However, the variety V_3 was on par with the varieties V_1 and V_2 .

The comparison of fertilizer levels indicated that the fertilizer level L_1 had significantly higher dry weight of earheads per plant than the fertilizer level L_2 .

Thus, it was observed that among the varieties V_2 had significantly higher dry weight of earheads per plant than the varieties V_3 and V_1 and the fertilizer level L_1 had significantly higher dry weight of earheads per plant than fertilizer level L_2 .

The interaction effects between varieties and fertilizer levels were not significant.

4 2 4 Mean total dry weight per plant

The dry weight of all plant parts such as leaves, stems and ears was summed up at respective samplings and data on mean total dry weight per plant are presented in Table 11 and depicted in Fig 5.

The data presented in Table 11 indicated that varietal differences in mean total dry weight per plant were statistically significant at 45 and 60 DAS.

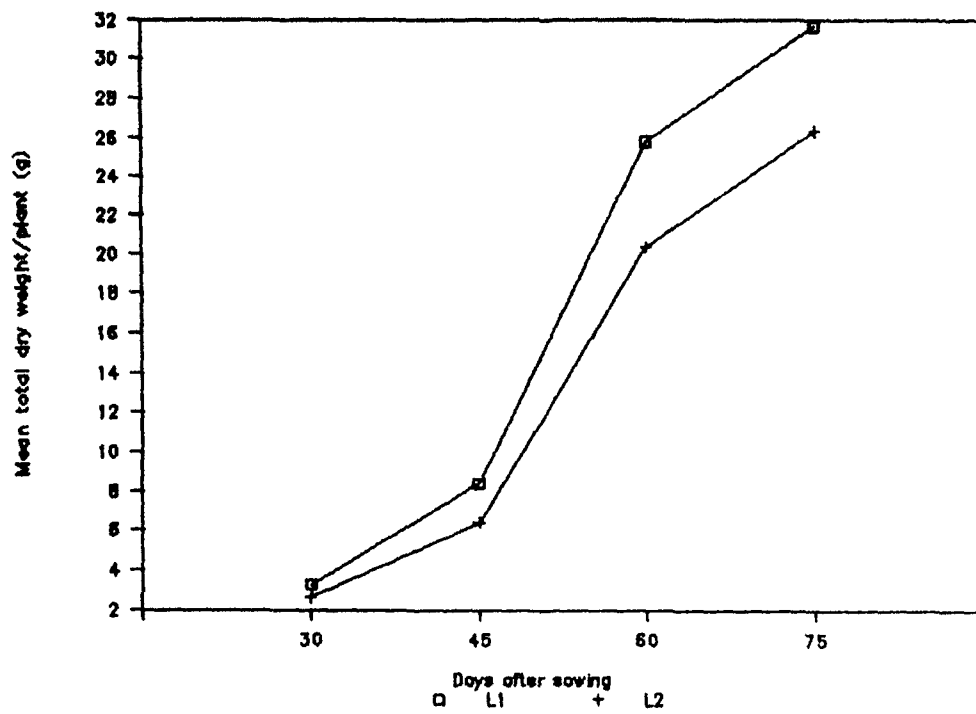
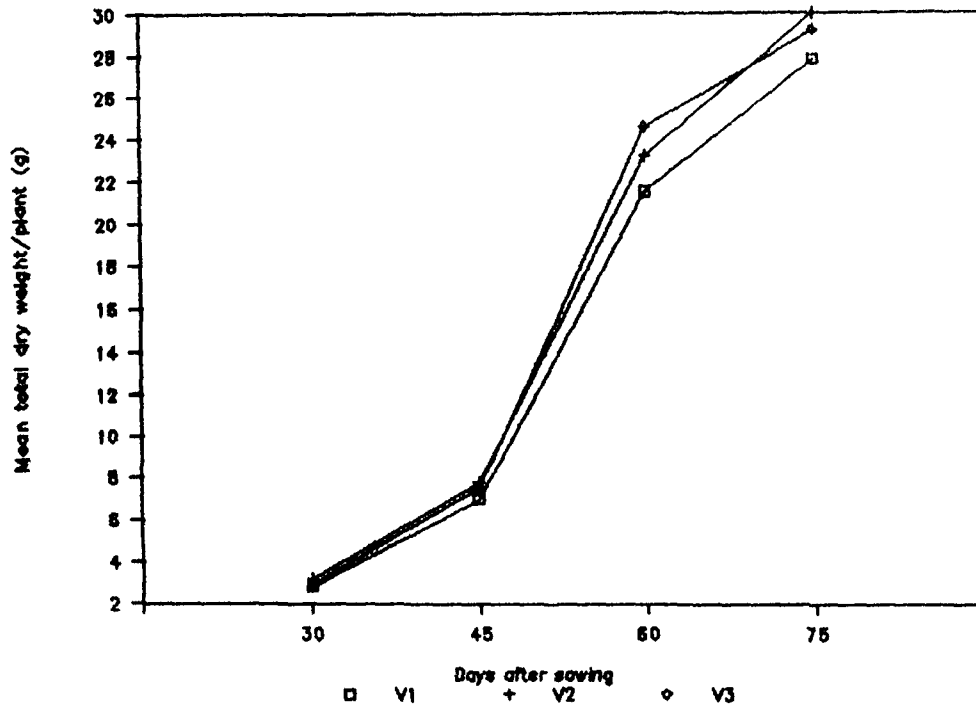
At 45 DAS, the highest mean total dry weight per plant was evident under the variety V_2 which was significantly

Table 11 : Mean total dry weight per plant (g)

| Treatment | Days after sowing | | | |
|----------------------------|-------------------|-------|-------|-------|
| | 30 | 45 | 60 | 75 |
| V ₁ (MACS-2496) | 2.83 | 6.98 | 21.49 | 27.81 |
| V ₂ (HD-2189) | 3.18 | 7.78 | 23.19 | 30.00 |
| V ₃ (NI-5439) | 2.95 | 7.56 | 24.58 | 29.19 |
| S.E. \pm | 0.207 | 0.165 | 0.688 | 0.881 |
| C.D. at 5 % | N.S. | 0.499 | 2.073 | N.S. |
| L ₁ | 3.30 | 8.43 | 25.80 | 31.67 |
| L ₂ | 2.67 | 6.46 | 20.37 | 26.33 |
| S.E. \pm | 0.169 | 0.135 | 0.562 | 0.719 |
| C.D. at 5 % | 0.508 | 0.407 | 1.692 | 2.166 |
| Interaction (V \times L) | | | | |
| S.E. \pm | 0.292 | 0.234 | 0.973 | 1.245 |
| C.D. at 5 % | N.S. | 0.705 | N.S. | 3.757 |

N.S. = Not significant.

Fig. 5 - Mean total dry weight per plant (g.).



V₁ - MACS - 2496

V₂ - HD - 2189

V₃ - NI - 5439

L₁ - 100 : 60 : 60 NPK kg/ha

L₂ - 50 : 30 : 25 NPK kg/ha

higher than the variety V_1 . Further it was observed that the variety V_2 was on par with variety V_3 and both the varieties were significantly higher than the variety V_1 . Variety V_3 had significantly more total dry weight per plant, than the variety V_1 but it was on par with the variety V_2 . The varieties V_1 and V_2 were also on par with each other.

At 60 DAS, the highest total dry weight per plant was recorded in the variety V_2 which was significantly higher than the variety V_1 . The varieties V_2 and V_3 were on par with each other.

Further, at 30 and 75 days of crop growth stages numerically the highest mean total dry weight per plant was observed under the variety V_2 and lowest mean total dry weight per plant was found under the variety V_1 .

The comparison of fertilizer levels indicated that fertilizer level L_1 had significantly higher mean dry weight per plant than the fertilizer level L_2 at all the crop growth stages.

Thus, it can be seen that comparison of the varieties for mean total dry weight per plant indicated that behaviour of the varieties was differential at 45 and 60 DAS. While the fertilizer level L_1 had consistently and significantly higher total dry weight per plant at all the sampling occasions.

Table 12 : Mean total dry weight per plant as affected by V x L interaction (g)

| Treatment | L ₁ | L ₂ | Mean | S.E.± | C.D. at 5 % |
|------------------|----------------|----------------|-------|-------|-------------|
| At 45 DAS | | | | | |
| V ₁ | 7.85 | 6.10 | 6.98 | 0.234 | 0.705 |
| V ₂ | 8.23 | 7.33 | 7.78 | | |
| V ₃ | 9.20 | 5.95 | 7.58 | | |
| Mean | 8.43 | 6.46 | | | |
| At 75 DAS | | | | | |
| V ₁ | 29.50 | 26.13 | 27.81 | 1.245 | 3.752 |
| V ₂ | 34.75 | 25.25 | 30.00 | | |
| V ₃ | 30.75 | 27.63 | 29.19 | | |
| Mean | 31.67 | 26.33 | | | |

The interaction effects were significant at 45 and 75 DAS. At 45 DAS, the treatment combination V_3L_1 had the highest total dry weight per plant and it was significantly higher than remaining treatment combinations. While the lowest total dry weight per plant was observed in treatment combination V_3L_2 and it was significantly inferior than remaining treatment combinations except V_1L_2 .

At 75 DAS, lowest and highest mean total dry weight per plant was observed in the treatment combinations V_1L_1 and V_2L_1 . The treatment combination V_2L_1 was significantly superior to remaining treatment combinations. While the treatment combination V_2L_2 was on par with treatment combinations V_1L_2 and V_2L_2 .

4.3 Days required for different growth stages

The experimental data on days required for different growth stages such as days required for initiation of heading, 50 per cent heading and physiological maturity are presented in Table 13.

4.3.1 Mean days required for initiation of heading

It can be seen from Table 13 that the varieties differed in respect of initiation of heading. The variety V_1 was required significantly more number of days than the varieties V_3 and V_2 . It is significant to note that variety

Table 13 : Mean number of days required for different growth stages

| Treatment | Days required for | | |
|----------------------------|-----------------------|---------------------|------------------------|
| | Initiation of heading | 50 per cent heading | Physiological maturity |
| V ₁ (MACS-2496) | 69.63 | 72.80 | 111.00 |
| V ₂ (HD-2189) | 62.30 | 64.00 | 107.00 |
| V ₃ (NI-5439) | 65.90 | 69.40 | 115.00 |
| S.E. \pm | 0.444 | 0.347 | --- |
| C.D. at 5 % | 1.338 | 1.045 | --- |
| L ₁ | 66.30 | 68.70 | 111.00 |
| L ₂ | 65.60 | 68.80 | 111.00 |
| S.E. \pm | 0.363 | 0.283 | --- |
| C.D. at 5 % | N.S. | N.S. | --- |
| Interaction (V x L) | | | |
| S.E. \pm | 0.628 | 0.491 | --- |
| C.D. at 5 % | N.S. | N.S. | --- |

N.S. = Not significant.

V₂ had early initiation of flowering which was significantly early than the varieties V₁ and V₃

The comparison of the fertilizer levels indicated that, higher or lower fertilizer level did not influence the initiation of heading

4 3.2 Mean days required for 50 per cent heading

The data presented in Table 13 indicated that the variety V₁ required significantly more number of days for 50 per cent heading than the varieties V₃ and V₂. The differences in number of days required for 50 per cent heading due to fertilizer levels were statistically not significant

4 3 3 Mean days required for physiological maturity

The data presented in Table 13 indicated that the variety V₂ had early physiological maturity than the varieties V₁ and V₃. The maximum days (115 days) required for physiological maturity to the variety V₃ and the minimum number of days (107 days) required to the variety V₂. The comparison of fertilizer levels indicated that there were no differences in the fertilizer level L₁ and L₂ for physiological maturity

The interaction effects between varieties and fertilizer levels in respect of days required for different growth stages were found to be not significant

4 4 Growth functions

In the present investigations, the effects of fertilizer levels and varieties on the physiological growth function viz , Absolute Growth Rate (AGR), Relative Growth Rate (RGR) and Net Assimilation rate (NAR) were studied. The data on these attributes are analysed statistically and the inferences therefore, are drawn on the statistical basis.

4 4 1 Mean Absolute Growth Rate (AGR)

The data pertaining to mean absolute growth rate are presented in Table 14. It can be seen from Table 14 that the varietal differences were statistically not significant. In general, AGR in these varieties increased upto 45 to 60 days of crop growth stage and thereafter it decreased.

As regards the fertilizer levels, it was evident from Table 14 that the AGR due to fertilizer level L_1 was significantly more than L_2 between 30 to 45 and 45 to 60 DAS.

The interaction effects between fertilizer levels and varieties were not significant.

4 4.2 Mean Relative Growth Rate (RGR)

The data regarding mean relative growth rate are presented in Table 15.

It would be seen from Table 15 that the varietal differences for relative growth rate were statistically not significant.

Table 14 : Mean absolute growth rate (g/day/plant)

| Treatment | Days after sowing | | |
|----------------------------|-------------------|-------|-------|
| | 30-45 | 45-60 | 60-75 |
| V ₁ (MACS-2496) | 0.34 | 1.10 | 0.47 |
| V ₂ (HD-2189) | 0.31 | 1.03 | 0.50 |
| V ₃ (NI-5439) | 0.30 | 1.07 | 0.31 |
| S.E. \pm | 0.051 | 0.078 | 0.076 |
| C.D. at 5 % | N.S. | N.S. | N.S. |
| L ₁ | 0.40 | 1.80 | 0.40 |
| L ₂ | 0.30 | 0.90 | 0.41 |
| S.E. \pm | 0.041 | 0.063 | 0.062 |
| C.D. at 5 % | 0.124 | 0.191 | N.S. |
| Interaction (V \times L) | | | |
| S.E. \pm | 0.072 | 0.110 | 0.108 |
| C.D. at 5 % | N.S. | N.S. | N.S. |

N.S. = Not significant.

Table 15a. Mean relative growth rate (g/g/day)

| Treatment | Days after sowing | | |
|----------------------------|-------------------|-------|-------|
| | 30-45 | 45-60 | 60-75 |
| V ₁ (MACS-2496) | 0.064 | 0.075 | 0.018 |
| V ₂ (HD-2189) | 0.063 | 0.071 | 0.015 |
| V ₃ (NI-5439) | 0.185 | 0.151 | 0.014 |
| S.E. \pm | 0.042 | 0.041 | 0.004 |
| C.D. at 5 % | N.S. | N.S. | N.S. |
| L ₁ | 0.065 | 0.122 | 0.016 |
| L ₂ | 0.143 | 0.076 | 0.016 |
| S.E. \pm | 0.034 | 0.034 | 0.003 |
| C.D. at 5 % | N.S. | N.S. | N.S. |
| Interaction (V \times L) | | | |
| S.E. \pm | 0.059 | 0.058 | 0.005 |
| C.D. at 5 % | N.S. | N.S. | N.S. |

N.S. = Not significant.

Similarly the fertilizer levels did not affect the RGR and hence the differences were not significant

The interaction effects between varieties x fertilizer levels were also not significant.

4 4 3 Mean Net Assimilation Rate (NAR) per plant

The data pertaining to mean net assimilation rate per plant are presented in Table 16

The data presented in Table 16 indicated that the varieties behaved differentially in respect of NAR. All the varieties had less NAR value between 30 to 45 and increased thereafter. All varieties V_3 for NAR throughout the crop growth stages. The variety V_3 had maximum NAR than the varieties V_2 and V_1 at 30-45 DAS while the lowest NAR value was observed in the variety V_1 . Between 45 to 60 days, the variety V_3 had maximum NAR than varieties V_2 and V_1 but the lowest value was observed in the variety V_2 . Between 60 to 75 days of crop growth stage variety V_3 had highest NAR than varieties V_3 and V_2 .

The comparison of fertilizer levels indicated that the fertilizer level L_1 had numerically higher NAR values than the fertilizer level L_2 except 30-45 DAS.

The interaction effects between varieties and fertilizer levels were ^{not} significant.

Table 16. Mean net assimilation rate (NAR) per plant
(g/dm²/day)

| Treatment | Between days after sowing | | |
|----------------------------|---------------------------|-------|--------|
| | 30-45 | 45-50 | 60-75 |
| V ¹ (MACS-2496) | 0.169 | 0.326 | -2.215 |
| V ² (HD-2189) | 0.179 | 0.296 | -4.132 |
| V ³ (NI-5439) | 0.195 | 0.348 | -1.908 |
| S.E. ± | 0.026 | 0.031 | 1.995 |
| C.D. at 5% | NS | NS | NS |
| L ¹ | 0.161 | 0.335 | -0.779 |
| L ² | 0.201 | 0.331 | -4.425 |
| S.E. ± | 0.021 | 0.026 | 1.629 |
| C.D. at 5% | NS | NS | NS |
| Interaction (V x L) | | | |
| S.E. ± | 0.037 | 0.44 | 2.822 |
| C.D. at 5% | NS | NS | NS |

N.S. = Not significant

4 5 Post harvest studies

The five plants which were selected for growth observations were harvested separately at maturity and post harvest data of these five plants were recorded

4.5.1 Mean number of productive tillers per plant

The data in respect of mean number of productive tillers per plant are presented in Table 17 and graphically shown in Fig 6

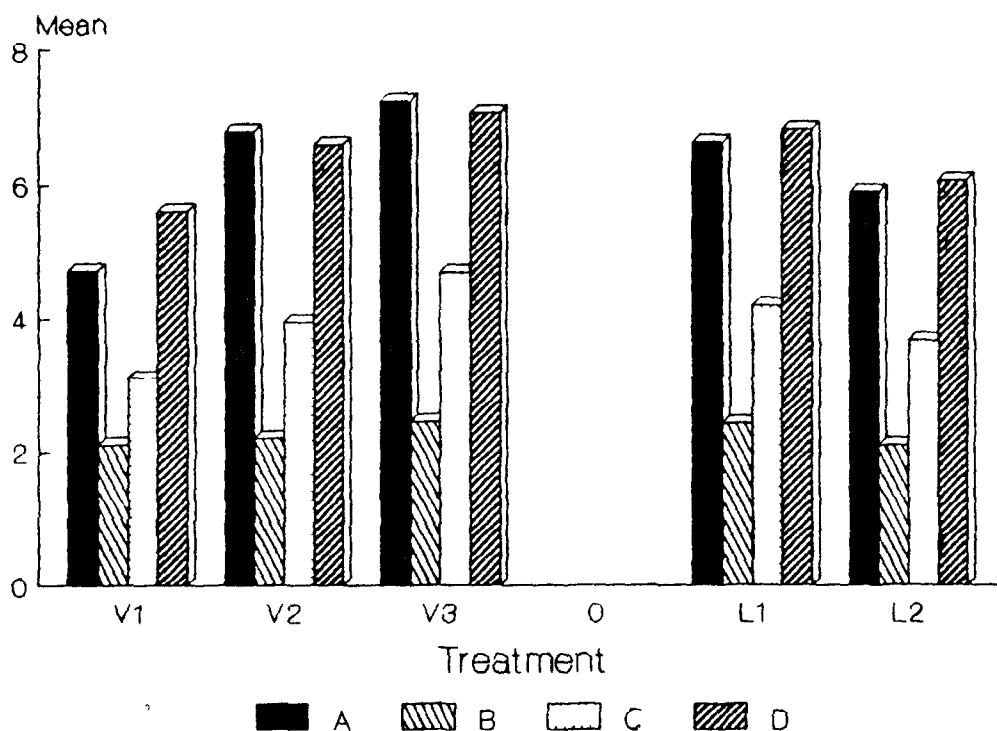
The data presented in Table 17 indicated that differences for mean number of productive tillers per plant were statistically significant in all the varieties. The variety V_3 had more number of productive tillers per plant

Table 17 : Mean number of productive tillers per plant, number of ears per plant

| Treatment | Mean No. of productive tillers/ plant | No. of ears/ plant |
|----------------------------|---|--------------------------|
| V ₁ (MACS-2496) | 4.71 | 5.60 |
| V ₂ (HD-2189) | 6.78 | 6.59 |
| V ₃ (NJ-5439) | 7.23 | 7.05 |
| S.E. \pm | 0.158 | 0.296 |
| C.D. at 5 % | 0.477 | 0.897 |
| L ₁ | 6.61 | 6.80 |
| L ₂ | 5.87 | 6.07 |
| S.E. \pm | 0.129 | 0.247 |
| C.D. at 5 % | 0.389 | 0.729 |
| Interaction (V x L) | | |
| S.E. \pm | 0.224 | 0.419 |
| C.D. at 5 % | N.S. | N.S. |

N.S. = Not significant.

Fig.8. Mean number of productive tillers per plant, number of ears per plant



A - Mean number of productive tillers per plant.

B - Mean number ear/main shoot

C - Mean number of ears/tiller

D - Mean number of ears/plant

V₁ - MACS 2496

V₂ - HD 2189

V₃ - NI 5439

L₁ - 100 : 60 : 60 NPK Kg/ha

L₂ - 50 : 30 : 25 NPK kg/ha

while variety V_1 had less number of productive tillers per plant. Thus, variety V_3 was significantly superior than variety V_1

As regards the effect of fertilizer levels, the mean number of productive tillers per plant was significantly higher under L_1 than L_2 . Thus, by increasing the fertilizer levels the productive tillers per plant were significantly increased

The interaction effects were not significant

~~The interaction effects were statistically not significant~~

4.5 3 Mean total number of spikelets per ear

The data regarding the mean total number of spikelets per ear are presented in Table 18

It can be seen from Table 18 that varietal differences were statistically significant in respect of spikelets number per ear. The variety V_3 had significantly less number of spikelets per ear, while variety V_1 had significantly more number of spikelets per ear than varieties V_2 and V_3 but the varieties V_2 and V_3 were on par with each other.

The fertilizer level L_1 had significantly more number of spikelets per ear than the fertilizer level L_2 .

The interaction effects between varieties and fertilizer levels were not significant.

4.5 4 Mean number of grains per ear

It can be seen from Table 18 that mean grain number per ear differed significantly. The variety V_3 had significantly less number of grains per ear while the variety V_1 had significantly more number of grains per ear than the varieties V_2 and V_3 .

Table 18 : Mean total number of spikelets per ear, mean number of grains per ear, grain weight per ear

| Treatment | No. of spikelets per ear | No. of grains per ear | Grain weight/plant | |
|----------------------------|--------------------------|-----------------------|--------------------|---------|
| | | | Main shoot | Tillers |
| V ₁ (MACS-2496) | 50.17 | 56.23 | 2.29 | 2.27 |
| V ₂ (HD-2189) | 45.28 | 50.00 | 2.51 | 2.45 |
| V ₃ (NI-5439) | 42.75 | 43.38 | 2.13 | 1.70 |
| S.E. \pm | 0.922 | 1.184 | 0.083 | 0.080 |
| C.D. at 5 % | 2.777 | 3.567 | 0.250 | 0.240 |
| L ₁ | 47.73 | 51.77 | 2.61 | 2.37 |
| L ₂ | 44.40 | 47.97 | 2.01 | 1.92 |
| S.E. \pm | 0.753 | 0.966 | 0.068 | 0.065 |
| C.D. at 5 % | 2.268 | 2.912 | 0.204 | 0.196 |
| Interaction (V x L) | | | | |
| S.E. \pm | 1.304 | 1.674 | 0.118 | 0.113 |
| C.D. at 5 % | N.S. | N.S. | 0.754 | N.S. |

N.S. = Not significant.

The fertilizer level L_1 had significantly higher number of grains per ear than the fertilizer level L_2

The interaction effects were statistically not significant.

4 5 5 Mean grains weight per plant (Main shoot and tillers)

The mean grain weight per plant of main shoot and tillers was recorded and data presented in Table 18

It can be seen from Table 18 that mean grain weight per plant of main shoot as well as tillers was maximum in the variety V_2 which was significantly higher than the variety V_3 but was on par with the variety V_1

The differences in grain weight per plant of main shoot and tillers were significant influenced by fertilizer levels. The comparison of fertilizer levels indicated that the fertilizer level L_1 produced significantly more grain weight per plant of main shoot and tillers than the fertilizer level L_2

The interaction effects between varieties and fertilizer levels were significant for grain weight of main shoot and data are presented in Table 19

Table 19 Mean grain weight of main shoot as affected by V x L interaction (g)

| Treatment | L ₁ | L ₂ | Mean | S E ± | C D at 5 % |
|----------------|----------------|----------------|------|-------|------------|
| V ₁ | 2 45 | 2.13 | 2 29 | 0 118 | 0 354 |
| V ₂ | 2 78 | 2 25 | 2 51 | | |
| V ₃ | 2 61 | 1 65 | 2 13 | | |
| Mean | 2 61 | 2 01 | | | |

The treatment combination V₂L₁ had the highest grain weight of main shoot while the lowest values for mean grain weight were observed under the treatment combination V₃L₂ which was significantly inferior than all other treatment combinations

4 5 6 Thousand grain weight

It is evident from Table 20 that variety V₂ had significantly higher 1000 grain weight, whereas variety V₁ had lowest 1000 grain weight but on par with V₃ and variety V₂ was significantly superior to variety V₃

The increasing fertilizer levels had significant effect on 1000 grain weight. Higher the fertilizer level more the thousand grain weight. The fertilizer level L₁ had higher 1000 grain weight than the fertilizer level L₂

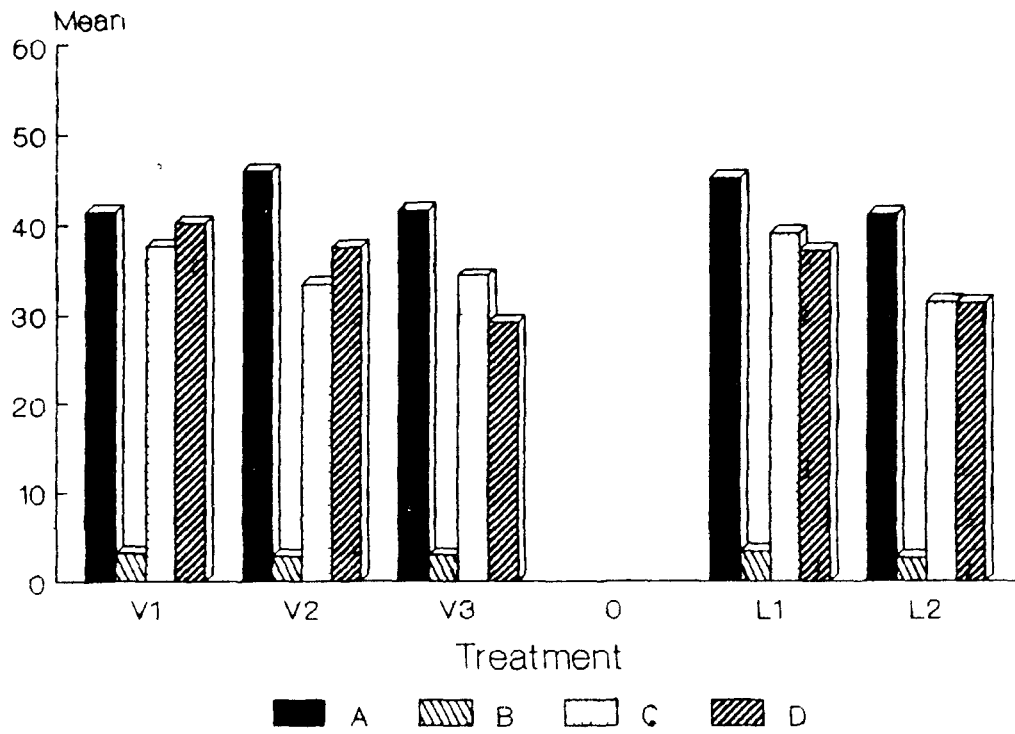
The interaction effects were found to be not significant

Table 20a. Yield and yield contributing attributes

| Treatment | Mean | | | |
|----------------------------|-----------------------|---------------------|--------------|-------------------|
| | 1000 grain weight (g) | Yield/net plot (kg) | Yield/ha (q) | Harvest index (%) |
| V ₁ (MACS-2496) | 41.39 | 3.19 | 37.55 | 40.21 |
| V ₂ (HD-2189) | 45.92 | 2.85 | 37.45 | 37.44 |
| V ₃ (NI-5439) | 41.57 | 2.91 | 34.31 | 39.11 |
| S.E. \pm | 1.021 | 0.112 | 1.341 | 2.44 |
| C.D. at 5 % | 3.075 | N.S. | N.S. | 6.763 |
| L ₁ | 45.02 | 3.31 | 38.94 | 37.03 |
| L ₂ | 40.91 | 2.66 | 31.26 | 34.14 |
| S.E. \pm | 0.833 | 0.092 | 1.095 | 1.833 |
| C.D. at 5 % | 2.511 | 0.276 | 3.299 | N.S. |
| Interaction (V \times L) | N.S. | N.S. | N.S. | 9.565 |
| S.E. \pm | 1.443 | 0.159 | 1.896 | 3.174 |
| C.D. at 5 % | N.S. | N.S. | N.S. | 9.565 |

N.S. = Not significant.

Fig. 7. Yield and yield contributing attributes



A - 1000 grain weight
 B - Yield per net plot
 C - Yield per ha.
 D - Harvest index

V₁- MACS - 2496
 V₂- HD - 2189
 V₃- NI - 5439
 L₁- 100: 60:60 NPK kg/ha
 L₂- 50 : 30:25 NPK kg/ha

4 5 7 Mean yield per net plot and per hectare

Grain yield of the three varieties at harvest was recorded on net plot basis and yield per hectare was computed. The relevant data are presented in Table 20.

The data presented in Table 20 indicated that the varietal differences were not significant and numerically highest yield per hectare was observed in variety V_1 while the lowest yield per hectare was observed in variety V_2 .

Fertilizer differences were significant and the comparison of fertilizer levels indicated that the fertilizer level L_1 had significantly higher yield per hectare than the fertilizer level L_2 . The interaction effects were not significant.

4 5 8 Mean harvest index

The harvest index of variety V_1 (MACS-2496) was significantly more as compared to variety V_3 while the lowest harvest index was observed in variety V_3 (NI-5439). The varieties V_1 and V_2 were on par with each other.

The comparison of fertilizer levels indicated that the fertilizer level L_1 had numerically higher harvest index than the fertilizer level L_2 but the differences were not significant.

The interaction effects between varieties and fertilizer levels were significant for harvest index and data are presented in Table 20b

Table 20b Mean harvest index as affected by V x L interaction

| Treatment | L ₁ | L ₂ | Mean | S E ± | C D at 5 % |
|----------------|----------------|----------------|-------|-------|------------|
| V ₁ | 34.93 | 45.49 | 40.21 | 3.174 | 9.565 |
| V ₂ | 43.38 | 31.51 | 37.44 | | |
| V ₃ | 32.78 | 25.43 | 29.11 | | |
| Mean | 37.03 | 34.14 | | | |

The treatment combination V₁L₂ had the highest harvest index (HI) while the lowest value for harvest index was observed under the treatment combination V₃L₂

4.6 Chemical analysis

The plant samples were collected at harvest and they were analysed for nitrogen, phosphorus and potassium content separately from stem, leaves and grains and determined as per method described in chapter III. The results are presented in following tables

4.6.1 (A) Mean per cent nitrogen content in stem

The data on mean per cent nitrogen content of stem are presented in Table 21

Table 21 : Mean per cent nitrogen, phosphorus, potassium and protein content in stems, leaves and grains at harvest

| Treatment | Nitrogen | | | Phosphorus | | | Potassium | | | Protein | | |
|----------------------------|----------|-------|-------|------------|-------|-------|-----------|-------|-------|---------|-------|-------|
| | S | L | G | S | L | G | S | L | G | S | L | G |
| V ₁ (MACS-2489) | 1.64 | 1.76 | 2.50 | 1.15 | 0.19 | 0.40 | 0.38 | 1.10 | 0.46 | 10.25 | 10.98 | 15.68 |
| V ₂ (HD-2189) | 1.60 | 1.81 | 2.52 | 0.15 | 0.19 | 0.41 | 0.37 | 0.09 | 0.46 | 9.81 | 11.31 | 15.75 |
| V ₃ (NJ-5439) | 1.68 | 1.77 | 2.57 | 0.15 | 0.19 | 0.41 | 0.40 | 0.09 | 0.46 | 10.50 | 11.03 | 16.08 |
| S.E. \pm | 0.084 | 0.055 | 0.093 | 0.003 | 0.002 | 0.006 | 0.010 | 0.004 | 0.004 | 0.524 | 0.343 | 0.583 |
| C.D. at 5 % | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| L ₁ | 1.51 | 1.83 | 2.53 | 0.14 | 0.20 | 0.43 | 0.40 | 0.09 | 0.47 | 9.44 | 11.46 | 15.82 |
| L ₂ | 1.75 | 1.72 | 2.53 | 0.15 | 0.19 | 0.38 | 0.36 | 0.09 | 0.44 | 10.94 | 10.76 | 15.82 |
| S.E. \pm | 0.068 | 0.045 | 0.076 | 0.002 | 0.001 | 0.005 | 0.008 | 0.003 | 0.004 | 0.428 | 0.280 | 0.476 |
| C.D. at 5 % | 0.206 | N.S. | N.S. | 0.007 | 0.004 | 0.015 | 0.024 | N.S. | 0.011 | 1.290 | N.S. | N.S. |
| Interaction (V \times L) | | | | | | | | | | | | |
| S.E. \pm | 0.119 | 0.078 | 0.132 | 0.004 | 0.002 | 0.009 | 0.014 | 0.005 | 0.006 | 0.741 | 0.485 | 0.825 |
| C.D. at 5 % | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |

N.S. = Not significant. S = Stem, L = Leaves, G = Grain

It can be seen from the data that differences in respect of mean per cent nitrogen content in all the varieties were not significant. However, variety V_3 (NI-5439) had numerically higher nitrogen content in stem than the varieties V_1 and V_2

The comparison of the fertilizer levels, revealed that the fertilizer level L_2 had significantly higher nitrogen content in the stem than the fertilizer level L_1

The varieties and fertilizer levels interactions were not significant.

(B) Mean per cent nitrogen content in leaves

It can be seen from the data presented in the Table 21 that differences in respect of nitrogen content in the leaves among the varieties, fertilizers levels and interactions were statistically not significant

(C) Mean per cent nitrogen content in grain

The varietal differences in per cent nitrogen content in the grains, fertilizer levels and interactions were statistically not significant

4 6 2 (A) Mean per cent phosphorus content in stem, leaves and grain

The data on mean per cent phosphorus content in plant parts viz., stem, leaves and grains at harvest are given in Table 21

The Table 21 indicated that the differences in phosphorus content in stem, leaves and grains in all the varieties were not significant

The comparison of fertilizer levels indicated that phosphorus content in stem was significantly higher in fertilizer level L_2 than L_1 . In case of phosphorus content in leaves and grains the fertilizer level L_1 had significantly higher phosphorus content than fertilizer level L_2 .

4 6 3 Mean potassium content in stem leaves and grain at harvest

The data on mean per cent potassium content in stem, leaves and grains are presented in Table 21.

The data presented in Table 21 indicated that the differences for potassium content in the stem, leaves and grains in the varieties studied were not significant

The comparison of fertilizer levels indicated that the fertilizer level L_1 was significantly superior than the fertilizer level L_2 for potassium content in stem and grains.

4 6 4 Protein content

(A) Mean per cent protein content in stem at harvest

The data on mean per cent protein content in stem, leaves and grain are presented in Table 21

The Table 21 indicated that the protein content in the stem was numerically highest in the variety V_3 as compared to the varieties V_1 and V_2 . However, the differences were statistically not significant.

As regards the fertilizer levels the data indicated that the fertilizer level L_2 had significantly higher protein content in the stem than the fertilizer level L_1 .

(B) **Mean per cent protein content in leaves and grains at harvest**

The data indicated that varietal differences, fertilizers levels and interactions were statistically not significant.

4 7 **Soil analysis**

4 7 1 **Soil analysis before experimentation**

The soil analysis before conducting the experiment was carried out to know the initial nutrient status in the experimental plot. The composite soil samples from 0 to 45 cm depth was taken and analysed for nitrogen, phosphorus and potassium content. The data pertaining to the initial content of nitrogen, phosphorus and potassium are presented in Table 22.

Table 22 Chemical composition of soil from the experimental field (0-45 cm)

| Sr No | Characteristics | | Method adopted |
|-------|------------------------------|--------|--|
| 1. | Available nitrogen (kg/ha) | 228.30 | Modified alkali permanate method (Saharawat and Burford, 1982) |
| 2 | Available phosphorus (kg/ha) | 21 32 | Spectronic-20 (Olsen's method) |
| 3 | Available potassium (kg/ha) | 470 40 | Flame photometer (Hanway Heidal, 1967) |
| 4. | pH | 8 10 | Glass electrode method (Piper, 1966) |

It was revealed that the available nitrogen, phosphorus and potassium was 228 30, 21 32 and 470 40 kg/ha. Thus, the soil was low in nitrogen, medium in phosphorus and high in potassium.

It could be seen from the Table 23 that the mean nitrogen, phosphorus and potassium present in soil after the harvest of experimental crop was 218 15, 18 90 and 460 13 kg/ha, respectively. However, the varietal differences were not significant. The data on fertilizer levels indicated that fertilizer level L₂ had significantly higher amount nitrogen, phosphorus and potassium content in the soil after harvest. It was further observed that interaction effects were statistically not significant.

Table 23 : Mean available N, P, K content in soil after harvest of crop

| Treatment | N | P | K |
|----------------------------|--------|-------|--------|
| V ₁ (MACS-2496) | 221.04 | 18.80 | 453.44 |
| V ₂ (HD-2189) | 218.29 | 18.61 | 462.64 |
| V ₃ (NI-5439) | 215.14 | 19.31 | 464.30 |
| S.E. \pm | 1.819 | 0.269 | 4.490 |
| C.D. at 5 % | N.S. | N.S. | N.S. |
| L ₁ | 213.53 | 18.03 | 450.70 |
| L ₂ | 222.79 | 19.80 | 469.60 |
| S.E. \pm | 1.485 | 0.219 | 3.666 |
| C.D. at 5 % | 4.474 | 0.661 | 11.046 |
| Interaction (V x L) | | | |
| S.E. \pm | 2.572 | 0.380 | 6.350 |
| C.D. at 5 % | N.S. | N.S. | N.S. |

N.S. = Not significant.

Chapter Opener Page

Discussion

5 DISCUSSION

A field trial to study the "Physiological analysis of growth and yield of wheat as influenced by fertility levels" was conducted during Rabi 1993-94. The results obtained are discussed in this chapter.

Fertility has pronounced effect on growth and development of crop throughout the growing season. The yield is dependent on soil fertility, fertilizers applied and varieties used. The higher yield is the combination of several morphological, physiological and environmental factors.

A comparison between different treatments in respect of yield (Table 20), revealed that application ^{of} two _λ fertilizer levels, the grain yield was more under higher level of fertilizer, indicating that higher the fertilizer level higher is the grain yield.

Thus, in general, by increasing the fertilizer level, there was increase in yield. Similar increase in grain yield due to increase the fertilizer levels was reported by Nagre and Bathkal (1978). They found that application of 120 kg N + 60 kg P₂O₅ per hectare recorded the highest and significantly more grain yield than 90 kg N + 45 kg P₂O₅/ha and 60 kg N + 30 kg P₂O₅/ha. Full dose of fertilizer in combination with eight irrigations recorded the maximum grain

yield. Soni et al. (1988) also found that the application of N, P and K at recommended level of 120 kg N + 80 kg P₂O₅ + 40 kg K₂O/ha could sustain high yield and maintain soil fertility. Further Auti and Kenjale (1985), Nakhtore and Kewat (1989) and Giorgio et al. (1989), observed increase in quality and yield under increase the fertilizer levels.

The variety MACS-2496 (V₁) produced more yield than varieties NI-5439 and HD-2189. Though varietal differences were not significant, the response of all these varieties to the fertilizer treatments was almost similar due to which the interaction effects were not significant. The increase in the yield of variety MACS-2496 by increasing the fertility levels (100.60 60 N,P,K kg/ha) was also observed by Bhaluya et al (1983) and they reported that the fertilizer level might have been responsible for higher grain yield. Similarly Nakhtore and Kewat (1989) observed that grain and straw yield increased significantly with increase in fertility levels from 0 to 100 per cent.

Reddy and Bharadwaj (1984) reported that the differences between 80 and 120 kg N/ha were significant and phosphorus application increased the numbers of ears, ear weight, fertility ratio of spikelets, 1000 grain weight, grain and straw yield.

The increase in yield due to increase in the fertilizer levels and varietal differences for yield may be because of two factors. This statement is supported by the data regarding the grain weight and number of grains per ear (Table 18). There was significant increase in number of grains per ear and grain weight per ear by increasing the fertility level. Similar increase in grain weight per ear was also reported by other workers (Muller et al., 1991, Dhuka et al., 1991). Upadhyaya and Dubey (1991) reported that the grain yield was highest with four irrigations and 120 kg N + 60 kg P₂O₅ + 40 kg K₂O. HD-2236 gave the highest grain yield and 1000 grain weight. In the present investigation, it was observed that the grain yield per ear decreased significantly by decreasing the fertilizer level (50 30 25 N,P and K kg/ha). The contribution of main shoot to the yield also changed i.e. between 2.61 and 2.01 gms. The contribution of main shoot for grain yield was maximum in variety HD-2189 (V₂). The results obtained in the present investigation are similar to that of Sihony and Pinthus (1988).

The yield of individual plant depends upon number of fruitful tillers including main shoot. The number of fruitful tillers per plant was significantly reduced under low fertility level (L₂) than L₁ (Table 18). As stated by Silberbush and Lips (1991), they reported that tiller number

per plant was correlated with dry matter yield and increased with nitrogen concentration. The reduction in fruitful tillers per plant was probably because of high mortality of tillers under higher fertility level, because of decrease in light intensity at lower layer, resulting the death of late formed tillers

The varieties differed significantly in respect of production of productive tillers per plant. The variety V₃ (NI-5439) produced significantly more productive tillers whereas variety V₁ and V₂ had lower number of productive tillers. The interaction of V x L was not significant. It is clear from the above discussion that grain yield differences under higher fertility level of different varieties was not mainly because of reduction in number of fruitful tillers per plant but may be due to other yield contributing characters. The grain yield per plant depends upon total number of ears per plant and number of grains per ear. In the present investigations, significant increase due to increased the fertility level in the grain yield per plant, main shoot and tiller was evident from the data in Table 17

The grain number per ear is another most important yield contributing character. In the present investigation the higher grain number per ear was observed in variety MACS-2496 (1) followed by V₂ (HD-2189) and V₃ (NI-439). The minimum

reduction in grain number per ear and grain weight per ear (g) in main shoot and tillers plant was recorded in the variety V₁. Thus when the fertility level was increased from 50 30 25 N, P and K kg/ha to 100 60 60 kg N, P and K per ha. This sort of reduction in grain number per panicle and yield of wheat was drastically reduced when fertilizer dose was reduced to 50 per cent of the recommended level by Pawar et al. (1988) at Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.). Similar results were reported by Reddy and Bharadwaj (1984), Soni et al (1989).

The reduction in grain number under lower fertility level may be either because of reduced spikelet number as stated by Langer and Liew (1973) or decrease the grain set as reported by Bhaliya et al (1983). However, reduction in grain number of different varieties under the influence of fertility levels were significant. By and large it can be, therefore, stated that all the varieties behaved in the similar fashion under different fertility levels. The grain number per ear depend on number of spikelets per ear and the grain setting per spikelet. It is evident from data (Table 18) that the spikelet number per ear of main shoot ear and tiller ear reduced significantly with decreasing the fertility levels. The reduction in spikelet number of main shoot ear was more pronounced than that of tillers. The maximum

reduction due to low fertility level was observed in variety NI-5439 (V_3) and minimum in variety MACS-2496 (V_1) both under L_1 and L_2 treatments. The spikelet number per plant was thus dependent mainly on main shoot spikelets in all the varieties as there were maximum spikelets in main shoot per ear in all the varieties. This observation, therefore confirms the results reported by Langer and Liew (1973) and Bhaliya et al. (1983). They also observed increase in spikelet number per ear of wheat due to increase in the fertility levels

The per plant grain yield depends not only on ear number per plant and grain number per plant but also on the grain size. The 1000 grain weight at harvest of the different varieties under different treatments was measured and observed that there was significant increase in 1000 grain weight of main shoot and average of the plant, when the fertility level was increased from 50:30:25 NPK kg/ha (L_2) to 100:60:60 NPK kg/ha (L_1). In case of 1000 grain weight in general increased with increase in fertility levels. The similar conclusion was drawn by number of workers, when they studied wheat varieties under increasing the fertility levels (Bhaliya et al. (1983), Sinbony and Pinthus (1988); Nagre et al. (1982); Reddy and Bharadwaj (1984)

The combined effect of number of grains and number of spikelets per plant and 1000 grain weight is seen in the

ear weight. As in case of other parameters, there was significant increase in the ear weight, when the fertilizer levels was increased. The varietal differences were also significant and per plant ear weight of variety V_1 (MACS-2496) was on par with variety V_2 (HD-2189) but significantly more than variety V_3 (NI-5439). The data was compared with per plant grain weight, it was observed that variety V_2 produced maximum grain yield which was on par with variety V_1 and V_3 . Thus it can be concluded that the ear weight per plant of variety V_2 was more than varieties V_1 and V_3 .

From the above discussion, it is observed that highest grain yield (4.96 gms) per plant was of the variety HD-2189 followed by the variety MACS-2496 (4.56) but there was maximum reduction in the grain yield per plant of variety NI-5439 both under L_1 and L_2 treatments due to which it lagged much behind variety MACS-2496. Thus, reduction in grain yield per plant under low fertility levels was mainly because of reduction in fruitful tillers per plant and grain number per plant and limited extent by grain size. However, this reduction was compensated by increased total number of ears per plant due to which grain yield per plant was more due to increase the fertility level.

A comparison between different treatments in respect of leaf area revealed that the leaf area per plant was

increased with increase with fertilizer levels (Table 3) throughout the growth period. Because of increased leaf area, total photosynthates produced by the plant might have been more as a result of which the grain yield and total dry matter yield per plant must have been increased. Because of increased leaf area, LAD (Table 5) was also increased due to leaf area per plant. In wheat, Belda et al (1997) studied the mineral nutrition of wheat organ and crop stage relationship and they reported that weight of youngest leaves at anthesis was a suitable indicator of biomass. Similar results in wheat were reported by Khalifa (1973). Early Nitrogen application effectively increased by LAD by increasing LAI.

Varietal differences were significant for most of the period. The leaf area per plant of all the varieties was increased due to increase the fertility level, however it was more marked in variety V₂ between 45-60 DAS which was grain filling period. This might have laid to more photosynthesis during grain filling period and net photosynthates must have been translocated to the sink which resulted in more yield per plant.

The total dry matter is the result of net photosynthesis in leaves and stem during vegetative phase and mainly leaves, ears and partly stem during reproductive phase.

after ear emergence. The total dry matter per plant includes dry matter of leaves, stem with sheath and ears. From the data in Table 11, it was observed that the total dry matter increased significantly due to increased the fertility levels. The total dry matter at initial stages was mainly because of stem dry matter but later on as ears and grains developed, it was mainly due to ear dry weight. The differences in total dry matter under different fertility levels after ear emergence were mainly due to differences in the ear weight. The total dry matter production of stalks per plant increased with increase the fertility levels. The fertilizers application increased the number of ears, ear weight, fertility ratio of spikelets, 1000 grain weight, grain and straw yield (Reddy and Bharadwaj, 1984, Nakhtore and Kewat, 1989, Chauhan and Ram, 1993). The varietal differences regarding total dry matter during later stages of growth were also mainly because of differences in ear weight. When ear dry weight was increasing at a faster rate, the accumulation of photosynthates in stem and leaves was exported toward the developing grains and earhead. Though there was no reduction in the stem dry matter during ear development, the rate of accumulation was slow down from 60 to 75 DAS onwards.

The increase in grain yield and total dry matter per plant due to increase the fertility level was compensated by the increased number of earheads per plant which resulted in increased grain yield.

As the dry matter was increased, there was proportionate increase in the grain yield per plant under the increased the fertility level. Thus, there was reduction in the translocation of photosynthates toward the grain. The reduction in the harvest index was reported by Singh and Stoskopf (1971) and they concluded that harvest index was positively correlated with vegetative growth. The harvest index in the present investigations was reduced from 37.03 to 34.14. When the fertility level increase from L_2 to L_1 . It is said that more the harvest index, more is the grain yield. This is proved in this experiment as the variety MACS-2496 had 40.21 per cent harvest index which had higher grain yield.

The height of the plant and days to different growth stages were also influenced by the fertility levels. The height of the plant increase significantly with increasing the fertility levels. Similar increase in plant height due to fertility levels was reported by Ray et al (1989).

The number of days required for initiation of heading, 50 per cent flowering and physiological maturity were not influenced by fertility levels and thus, the interactions were not significant. This conclusion is supported by Bharud and Patil (1989).

From the studies on growth functions, it can be concluded that AGR of dry matter, in general, increased with

increasing the fertility level, whereas RGR with few exceptions decreased with increasing the fertility levels. This might be due to shedding effects.

The variety MACS-2496 had highest AGR upto 60 DAS but at later on it dropped down. The RGR in variety NI-5439 was higher during most of the growing period, followed by MACS-2496 and HD-2189 which may have favoured in maintaining the higher number of fruitful tillers and high yield of these varieties. The NAR represents the photosynthetic efficiency of leaves and according to Weston (1947), increase in dry matter yield was associated with increase in mean leaf area. These assimilates might have been efficiently used for economical yield rather than biological yield which resulted in higher harvest index.

As the age of crop increased, there was increase in NAR values with increase in fertility level. This may be accounted for higher LAI, which may result in negative values because of shedding effect and thus ultimately reduced the grain yield. In general, there was inconsistent trend in NAR values as fertility levels increased.

To summarize, it would appear from the present results that variety MACS-2496 was more suitable for cultivation for obtaining high yield by increasing the fertility level.

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*Summary &
Conclusion*

6. SUMMARY AND CONCLUSIONS

A field experiment to study "Physiological analysis of growth and yield of wheat as influenced by fertility levels", was conducted at Post Graduate Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra State) during Rabi, 1993-94 to understand the basis for differential varietal response to different fertility levels. The field trial consisting of three varieties namely MACS-2496 (V_1), HD-2189 (V_2) and NI-5439 with two fertility levels (L_1) - 100:60:60 NPK kg/ha and (L_2) - 50:30:25 NPK kg/ha were used. The growth observations were recorded at 15 days interval. Similarly, for dry matter studies the plant samples consisting of five randomly selected plants were collected. The following broad conclusions are drawn from the studies.

1. The grain yield per hectare was higher with high fertility level.
2. The higher grain yield per hectare was mainly because of the increase in number of ears per plant.
3. Under high fertility level the yield attributes such as tiller number, grain number per ear and 1000 grains weight had higher values and affected thus, the yield was higher under high fertility level.

4. The total dry matter and dry matter of stem, leaves and ears per plant were increased with increase in fertility level.
5. The value of growth functions such as AGR and RGR somewhat were reduced with increase the fertility levels. While, NAR values were higher under higher fertility levels.
6. Height of the plant increased with increase in fertility level. Similarly leaf area and leaf area index per plant increased with increase in fertility level. however, decline in LAI after anthesis was more marked under higher fertility level.
7. All growth stages such as initiation of flowering, 50 per cent flowering and physiological maturity were not affected with increase in fertility level.
8. The uptake of N was higher under high fertility level.
9. The varietal differences for yield were not significant. However, the variety MACS-2496 was more suitable under higher fertility level.
10. The grain yield was appeared to be dependent on the number of productive tillers, number of grains/^{ear} and

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1000 grains weight. All these yield contributing characters were favourably influenced by the high fertility level.

11. Among the varieties, the variety HD-2189 was found to be bolder having higher 1000 grain weight.
12. In all the varieties the LAI was highest at 60 days and thereafter, it declined with time.

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Vita

8. VITA

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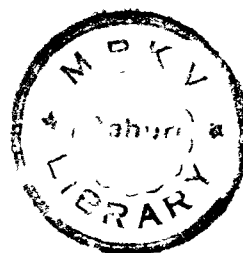
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