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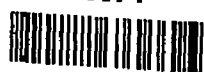
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**EVALUATION ON THE KINETICS OF NITROGEN
ACCUMULATION IN THE WHEAT GRAIN IN
RELATION TO YIELD**

K. SIVA SANKAR NAIK

**DIVISION OF GENETICS
INDIAN AGRICULTURAL RESEARCH INSTITUTE
NEW DELHI - 110 012**

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1993

EVALUATION ON THE KINETICS OF NITROGEN ACCUMULATION IN THE
WHEAT GRAIN IN RELATION TO YIELD

BY

K. SIVA SANKAR NAIK

A thesis submitted to the Faculty of Post-Graduate School,
Indian Agricultural Research Institute, New Delhi,
in partial fulfilment of the requirements,
for the degree of

DOCTOR OF PHILOSOPHY

IN

GENETICS

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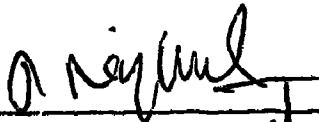
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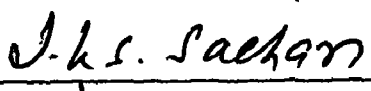
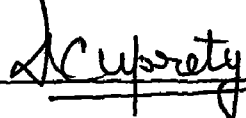
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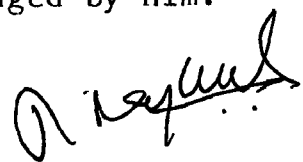
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CERTIFICATE

This is to certify that the thesis entitled, "Evaluation on the kinetics of Nitrogen accumulation in the wheat grain in relation to yield" submitted to the Faculty of Post-Graduate School, Indian Agricultural Research Institute, New Delhi, in partial fulfilment of the requirements, for the award of the degree of Doctor of Philosophy in Genetics, is a record of bona fide research work carried out by Sri K. Siva Sankar Naik, under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma. Also, the assistance and help received during the course of the investigation have been duly acknowledged by him.

New Delhi
Dated: 17th April, 1993


(P. Raghavaiah)
Chairman,
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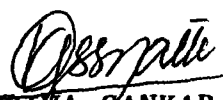
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1. INTRODUCTION

Wheat is the world's first and foremost important annual cereal crop, both in area and production. Wheat cultivation is concentrated most in northern hemisphere. At present, wheat provides 20 per cent of the total food calories for the people of the world and is staple food in at least 43 countries. About 14 per cent of world area is grown in the Indian subcontinent. Production trends of wheat in India for the periods 1950-51 to 1992-93 clearly shown a very rapid rate of increase in area, production and productivity. The increase has been particularly rapid after the mid-sixties. A large part of this advance has been contributed by a few major genes such as the 'Norin-10' dwarfing genes in bread wheat.

With the introduction of high yielding dwarf varieties of wheat, like Sonora 63, Sonora 64, Lerma Rojo 64A and Mayo 64 from Mexico in 1963; systematic breeding efforts were initiated in India to develop high yielding varieties. As a result of this, several varieties which were markedly superior to the old Indian wheats for yield and other characters were developed and released for commercial cultivation. This lead to the increased production of wheat from mere 12 million tonnes in 1964-65 to 57 million tonnes in 1992-93, a remarkable achievement which has no parallel in the world. It has also been observed that the highest yields obtained have remained almost static since 1970-71. Some of our best varieties have become susceptible to diseases like rusts and smuts.

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An analysis of factors limiting yield in the present cultivars show that the three major components of productivity in this crop i.e. number of grains per spike, grain weight and tiller number per unit area which are negatively associated. It has also been observed that improvement in one yield component is offset by reduction in other. Such an adverse interrelationship among the principal yield components act as a major constraint in breaking the existing yield barriers in this crop. Genetic approaches for the improvement of yield and quality are, however, much handicapped because of certain unfavourable association of characters namely, negative correlation between grain yield and protein content. It is of immense help to bring about favourable modifications in the interrelationship among the yield components and also protein, thus reducing compensation effect among them.

Along with the improvement in yield, it is necessary to upgrade the nutritional quality of wheat by increasing the protein quantity and quality. This is of much importance in countries like India where a large majority of people are vegetarian and consume cereals as their staple food. Since more than seventy per cent of Indian population live in rural areas under economic conditions in which they can hardly afford to buy protein rich food products from animal sources. Moreover, the principal sources of plant proteins (cereals mainly) represent sixty per cent of the world protein supply. Upgrading the quality of the staple diet would serve eminently the objective of overcoming the problem of malnutrition. This will maintain the calorie-protein intake balance and will not make extra demand on the purchasing power of common people nor

will it necessitate change in their food habits. Systematic efforts should now be intensified to upgrade Indian wheats for protein and other nutritional qualities as well as processing properties. Diversification of wheat based products necessitate the development of suitable varieties for specific end-uses such as for making chapati, bread, cakes, biscuits etc.

In view of the above mentioned aspects the present investigations were carried out with an objective of evaluating various strains belonging to three different maturity groups of bread wheat developed for high protein and yield.

It is also important to have a knowledge about the ability of individual genotypes to accumulate the nitrogen at a faster rate and increase the protein content. In view of this, an attempt was made to identify the genotypes from early, medium and late maturity groups with better capability to accumulate nitrogen in other words protein content during the grain development periods. The genotypes with high ability to accumulate protein at a faster rate and having higher yields will be of immense importance, otherwise they can be used as superior genotypes in the improvement of protein breeding programmes as high protein efficient donors.

Our investigations include twenty-five entries, out of which seven early, thirteen medium and five late maturing strains alongwith old and new cultivars.

2. REVIEW OF LITERATURE

In the review of literature cited, an attempt has been made to provide information related to our present investigation i.e. correlation between yield and yield attributes, direct and indirect effects of these parameters on yield, heritability, genetic advance and quality studies. The relevant literature, available on the above aspects, has been reviewed under the following heads:

2.1 Correlation between yield and yield attributes

2.2 Path coefficient analysis

2.3 Estimates of heritability and genetic advance of yield attributes

2.4 Quality studies

2.1 Correlation between yield and yield attributes

Correlation studies between yield and other traits have been of an immense help in developing a plant ideotype. The importance of the knowledge of the association between the various characters will help in improving the net economic growth of the crop. The relationship between yield components would, indicate the changes brought about in them when selection pressure is exerted on one character even though the other traits are not subjected to any selection.

The idea of correlation was first presented by Galten (1989). Later it was elaborated by Fisher (1918) and Wright (1921). The directly observable phenotypic correlation does not indicate the magnitude of direction of genetic correlation

which represents a true picture of relationship between the genes controlling the two characters, since it combines genetic and environmental causes of correlation. In order to have desired information, correlation of two characters needs to be partitioned into genetic and environmental correlations.

Clark (1924) showed that environmental conditions have considerable impact on correlation values. He observed that the degree of correlation between date of heading and plant height in wheat increased with increasingly unfavourable environmental conditions, due to rust and drought, otherwise the correlations were negative and not important.

Bridgeford and Hayes (1931) reported that yield was positively correlated with 1000-grain weight, date of heading and plant height. Weibel (1956) studied phenotypic, genotypic and environmental correlation coefficients using P_1 , P_2 , F_1 and F_2 generations. High grain yield was found to be correlated with high kernel weight, but due to low heritability of the grain yield, it was suggested that selection for kernel weight should be of practical value in F_2 with subsequent testing for yield in later generation. This was also reported by Sikka and Jain (1958).

Nandpuri et al. (1959) reported non-significant correlations of heading date with plant height and effective tillers and plant height. Gandhi et al. (1964) using 90 varieties of Indian wheats observed that in general, genotypic correlation coefficients were of the same magnitude as the phenotypic ones for most of the characters studied. The results showed high

positive correlation values of grain yield with ear per plant, 100-grain weight and grains per ear and spikelets per ear had high positive correlation with grain number per ear and days to flowering, whereas ears per plant showed high negative correlation with plant height.

Malik Saghir Ahmed et al. (1968) calculated correlation coefficients between yield and its components viz., fertile number of tillers per plant, 1000-kernel weight, spike length, number of kernels per spike and number of spikelets per spike, date of heading and protein content in F_2 progenies of crosses between a series of dwarf wheat varieties. A significant positive correlation was found between yield and number of fertile tillers per plant, 1000-kernel weight, spike length and number of kernels per spike but these values were significantly negative between yield and protein. Similar results were obtained by Knott and Talukdar (1971), Aulakh and Virk (1973), Jain and Singh (1973), Virk (1973) and Singh (1982).

Virk and Verma (1972) studied the phenotypic correlations in 20 wheat populations consisting of 11 diverse varieties and 9 F_2 populations. It was observed from their results that spike number and 100-grain weight have shown positive and highly significant correlations with yield.

Syme (1972) reported high correlations for days to flower, plant height, 1000-grain weight yield, but not yield per plant. Vorobev (1972) observed significant correlation coefficient values between yield and weight of grain per ear and per plant in bread wheat ($r = 0.792$ and 0.740 respectively) and Macroni wheat ($r = 0.994$ and 0.883 respectively). Correlation with 1000-

grain weight and number of grains was lower especially in bread wheats. For number of ears per unit area, the values were $r=0.637$ in bread wheats and $r=0.546$ in Macaroni wheats.

Singh et al. (1973) showed that yield had a significant and positive genotypic correlations with ear length and number of fertile spikelets per spike. Whereas, at phenotypic level positive correlations were observed between yield and the number of fertile tillers per plant and at environmental level, number of fertile tillers per plant and of grains per spike showed a significant and positive correlations. Positive correlation was found between yield and number of grains and weight of grains per ear in F_3 by Boyadhieva (1974) and also by Zonjic and Jovanovic (1966).

Barriga (1974) reported that number of spikes per plant and earliness were positively correlated with yield. Number of spikes per plant was positively correlated with earliness. The number of grains per spike was positively correlated with height but negatively correlated with 1000-grain weight and it has a strong positive direct effect on yield. Earliness and plant height showed non-significant values with yield. Number of spikes, earliness and number of grains per spike are the principal yield components and 1000-grain weight and height are the secondary ones. Dunder (1974) indicated positive correlations of yield with characters such as productive tillers ($r=0.64$), grain weight per ear ($r=0.43$), number of grains per ear ($r=0.40$) and 1000-grain weight ($r=0.23$). Jaimini et al. (1974) reported in wheat that grain yield was significantly and positively correlated with number of spikes per plant, number

of spikelets per spike, and 1000-grain weight. Days to heading showed a significant negative association with grain yield.

Mcneal et al. (1972) reported that grain yield was more closely related to heads per unit area than kernels per head or kernel weight. Jain et al. (1975) found that grain yield had a high positive correlation with spike number, spikelets per spike and seeds per spike in all generations studied.

Jain and Singh (1975) worked out the correlation coefficients of 18 yield and morphological characters involving 16 cultivars representing 4 different height groups, i.e. tall, one gene dwarf, two gene dwarf and three gene dwarfs. In three genes dwarf group, length and 1000-grain weight were correlated significantly and positively with yield. In the two gene dwarf group, the correlation values of grain weight with days to flowering and spikelets per ear were found to be significant and positive. Randhawa et al. (1975) indicated that genetic variations were high for 1000-grain weight, plant height, peduncle length and yield per plant. Positive significant genotypic and phenotypic correlations between yield and number of tillers per plant, ear length, number of grains per ear and peduncle length were observed.

Stepanov and Rudenko (1975) observed that the height and various yield components in the hybrids and their parents, showed nonsignificant correlations. The highest correlation was observed between height and number of grains per ear in the F_1 generations. Virk et al. (1977) reported in three bread-wheat crosses that grain yield showed a positive and significant association with plant height, spike number, grain

number and grain weight. They also reported that the correlation of plant height always resulted from its indirect association with other traits correlated with yield.

Ali Ahmed Pianchi^{et al} (1978) found in wheat that yield was positively correlated with height, spikes per plant, spikelets per spike, grains per ear, florets per spike, floret fertility and ear length. Absence of correlation of seed weight with yield has also been noted. Abakumenko (1979) observed in winter wheat that number of tillers was negatively correlated with lodging resistance and components affecting grains weight per ear. Yield per ear was mainly determined by number of grains per ear and was little affected by ear density. Number of grains per spike depended on number of spikelets, spike length and especially number of grains in the spikelets.

Devendra Singh et al. (1979) reported that the grain yield was found positively associated with grain number and 1000-grain weight. Multiple correlation coefficient studies showed that these two factors viz., grain number and 1000-grain weight, along with flag leaf area accounted 98 per cent of total variation in the yield. Larik (1979) reported in fifteen phenotypically stable mutants of wheat that grain yield per plant was positively correlated with tiller number per plant and grain number per spike. Grain number per spike was positively correlated with spike length but negatively with tiller number.

Efremova and Pospelova (1980) worked on phenotypic correlations between yield and its components in various winter wheat varieties. They found positive correlation between yield

and its components in all the varieties studied. Sinha and Sharma (1980) also reported that grain yield in wheat cultivars NP-884, S-227 and S-308 was positively correlated with ear length, fertile spikelets per ear, 1000-grain weight, grains per ear, plant height, effective tiller number per plant and days to maturity. It was also reported that all these characters were mutually correlated with each other.

Ghuzov and Shuman (1981) reported that the most useful correlation from the point of view were those between grain yield per main ear and its components. Kumbhar et al. (1981) studied correlations in a wheat variety 6591. The results revealed that all the characters studied viz., spike length, spikelets per spike, seeds per spike, spike yield and yield per plant exhibited a strong positive correlation with their possible combinations. Kumbhar et al. (1982) estimated phenotypic correlation coefficients in durum and bread wheats and the results revealed that the plant productivity was most strictly affected by seeds per square metre and harvest index followed by spikes per square metre.

Correlation studies by Singh (1982) revealed that grain yield showed a high positive correlation with productive tillers and grains per spike. Spike length and 1000-grain weight also showed slight positive correlation. Plant height showed negative correlations with yield. Among the yield components productive tillers with grains per spike and plant height with spike length exhibited high positive correlations which means that selection for these characters would result in improvement of other characters.

Vedrov (1982) reported in spring wheat that yield was correlated with all its components. Sota (1983) in durum wheat estimated correlation coefficients between the stem length and grain yield and found that the correlations between these two characters were positive but low.

Jizeng (1984) found that the peduncle size and width of flag leaf positively correlated with grain weight, while no correlation was observed between the number of grains per ear and ear length.

Tanno and Goto (1985) studied variations in harvest index in F_2 derived lines of spring wheat crosses and found that variation for harvest index ranged from 32.6 to 47.7 per cent. The studies also revealed that there were positive correlations between grain yield and total dry matter and between grain yield and harvest index.

Gharzai (1985) analysed the data from the F_1 - F_5 of 4 crosses involving 4 high protein and two moderately low protein cultivars and revealed that, grain protein content and grain yield were negatively correlated, correlation coefficient values varying from close to zero to -0.56 between generations. The major components of grain yield were number of grains per plant and number of spikes per plant.

Rychtarik (1985) concluded that the coefficient of correlation between yield and both in ear number per square metre and number of spikelets per ear were high (0.715 and 0.448 respectively) and highly significant.

Vlakh and Smochek (1986) in a study of many varieties and promising lines under 2 stand densities (400 and 700 fertile tillers per square metre) variance in grain yield was attributable primarily to number of plants in the stand and number of developed grains in the main ear. Kachur (1986) established a high positive correlation between grain weight per ear and grain weight per plant.

Kolomiets (1986) in a study of F_1 - F_3 hybrids revealed a positive correlation ($r=0.443-0.929$) between grain weight and degree of productivity tillering in F_1 , grain weight per plant was closely correlated with the number of grains per ear and also with 1000-grain weight in the F_1 (with a decline in subsequent generations) plant height was most closely related with the length of uppermost internode.

Mahdy (1988) reported negative genotypic correlations between grain protein per cent and each of grain yield per plant ($r=-0.88$), spikes per plant (-0.92) and 1000-grain weight (-0.80) and a positive genotypic correlation between protein and each of heading date (0.66) and plant height (0.91).

Auang et al. (1989) reported that the genotypic correlation coefficients were generally higher than phenotypic and environmental correlation coefficients. Existence of correlations between grain yield, grain weight and all quality traits was reported by Barrett et al. (1989). Dolotovskii and Nikonov (1989) calculated the genotypic correlation coefficients of 12 bread wheat varieties grown at 2 sites. The correlations in many cases differed with site. For example, the correlations between grain weight per square metre and 1000-grain weight was

not significant in the north east forest steppe zone but was 0.71 in the steppe zone of Russia.

Hadjichristodoube (1989) computed environmental correlation coefficients among all pairs of five traits, namely, grain yield, heading date, tillers per square metre, plant height and 1000-grain weight. Using 30 T. durum and 30 T. aestivum, varieties grown in 18 environments. Grain yield was significantly correlated with the other 4 traits in almost all varieties. The mean correlation coefficients over all varieties ranged from 0.58 to -0.83 for durum wheat and from 0.66 to 0.88 for bread wheat. The correlation coefficients between heading date and the other traits were also significant ranging from -0.45 to -0.79 in durum wheat and -0.61 to -0.85 in bread wheat. These values between tiller number and plant height and 1000-grain weight were smallest (0.19-0.32) in durum wheat and 0.39-0.60 in bread wheat.

Li (1989) reported that plot yield was significantly and positively correlated with grains per spike, 1000-grains weight, biomass and economic index but negatively with plant height and fertile spikelets number. The contribution of first 4 principal parameters to the total variation was more than 85 per cent.

Lin et al. (1989) found a negative correlation between grain yield and protein content. Oliveirocamargo (1989) reported positive and highly significant phenotypic correlation between yield and ears per plant, plant height, grains per ear and 100-grain weight. It is possible to select semidwarf plants with high yield potential, high number of grains per ear.

more ears per plant and high 100-grain weight.

Sandhu and Roshan Lal (1989) evaluated 60 genotypes for 8 yield components during 1984-85, grain yield per plant showed significant positive correlation with tiller number per plant, number of spikelets per spike 100-grain weight and plant height.

Zhang et al. (1989) showed that grain protein content was more highly correlated with yield components than with other traits but was most highly correlated with amino acid content. Physiological properties were significantly correlated with quantitative characters. Protein variation caused by yield components, physiological and morphological characteristics was 44.5, 31.7 and 27.9 per cent respectively.

Deshmukh et al. (1990) found significant positive correlations between grain yield and grain weight per ear, days to flower, tiller number, 1000-grain weight and biomass/m² under rainfed condition and for grain weight per ear, harvest index and spikelets per ear under irrigated condition. Iqbal Singh et al. (1990) also reported genotypic correlations to be generally higher than the corresponding phenotypic correlations. Significant positive correlations of total biomass with all six other characters except 1000-grain weight were recorded. Lungu et al. (1990) concluded that the relationship between yield and protein content was negative and significant within all generations of their study.

Kapoor and Luthra (1990) reported a repulsion phase linkage between the characters involved in the correlations yield per plant Vs spike number and spike number Vs. 1000-grain weight. Li (1990) showed a negative correlation between grain

protein content and each of grain weight per plant, 1000-grain weight and ear length, between wet gluten content and both of number of spikelets per ear and grains per ear and between precipitation value and each of number of ears per plant, grain weight per plant and height. In a study with 16 promising wheat cultivars, Navtolela et al. (1990) found no clear relationship between grain yield and 1000-grain weight and test weight.

Saini et al. (1990) reported that grain yield was correlated with ears per plant in all the crosses and environments and with biological yield in all crosses and environments except one. Correlations with other characters tended to vary depending on the cross and environment.

Aguilar-Mariscal and Hunt (1991) stated that wheat yields are often closely related to spike number per unit area and found that there exists a positive relationship of grain yield to spike number per unit land area. The results of Palilvola and Ral'ko (1991) suggested that grain weight per plant, number of fertile tillers and grain weight per ear were closely correlated. Number of grains per ear was closely correlated with ear length number of spikelets and florets per ear.

Thakre and Sontakey (1991) while studying the influence of environment and generation on character association in bread wheat concluded that yield correlations were substantially influenced by environments and generation, however, tillers per plant and 1000-grain weight showed considerable consistency in their relationship with grain yield and are recommended for use in selection.

2.2 Path coefficient analysis

Path coefficient analysis was first developed and described by Wright (1921) as a tool in genetic analysis. The technique of path coefficient analysis serves as a mean of separating direct and indirect contributions of various factors. Path coefficient analysis is a standardised partial regression coefficient analysis and as such measures the direct influence of one variable upon the other and permits the separation of correlation coefficients into components of direct and indirect effects.

Li (1955) emphasized the great use of this technique in genetics and plant breeding studies. Dewey and Lu (1959) pointed out that this analysis is a very valued tool in detecting the real merit of characters contributing towards yield. The technique of path coefficient analysis helps to separate the individual effects of characters in question, rather than evaluating it, only on the basis of its environmental influence on the covariance between the two characters in question. Johnson (1955) pointed out that the genotypic correlation coefficients provide a measure of genotypic association between characters and gives an indication of the characters that may be useful as the indicators of the more important ones under consideration. They may also help to identify characters that have less or no importance in the selection programme. Genotypic correlations are necessary for studying the real or genotypic variation in different yield contributing characters and the manner in which environmental variation affects the expression of such variation. Dewey and

Lu (1959) found that in crested wheat grass, fertility and plant size were two factors that exerted the greater influence, both directly and indirectly upon seed yield, whereas seed size and spikelets per spike were unimportant. The studies of Fonseca and Patterson (1968) on the path coefficient analysis in winter showed direct effect of the number of tillers (0.976) on the grain yield but it was offset to certain extent by the indirect effect of grains per spike (-0.347), which gave the negative value. Grain number of the main spike and grain weight showed positive values for direct effect (0.718 and 0.317 respectively) and negative values for indirect effects on the yield.

Virk and Verma (1972) used path coefficient analysis in nine F_2 populations and 11 varieties of wheat. They reported that tiller number and 1000-grain weight had both direct and indirect influence on yield. Aulakh and Virk (1972) reported in wheat that 1000-grain weight had the maximum direct effect on grain yield. The grain hardness also had an indirect effect through this trait but its direct effect was negative. This all showed that only 1000-grain weight was the important component of grain yield which could be used as the basis for selection.

Path coefficients were worked out in a collection of 11 wheat varieties by Virk and Singh (1972). Their studies revealed that the 100-grain weight was the most important character influencing yield followed by the ears per plant. Jaimini et al. (1974) observed in wheat that the number of spikes per plant had the highest direct effect followed by the number of spikelets per spike and 1000-grain weight. Jain

et al. (1975) observed that the seeds per spike and spike number have a high direct influence on grain yield in wheat.

From the path coefficient analysis in wheat by Ali Ahmed Pianchi et al. (1978), it was observed that effects of florets per spike, floret fertility, maturity and ear length generally tended to be negative. However, effects of floret fertility are more important than others. Similarly, effects via spikes per plant, and grains per ear are positive and stronger, particularly in the latter case. Direct effects of these two characters seem to have precipitated in correlations with yield, besides contributing to correlations of other characters with yield in positive direction. Indirect effects via seed weight on other characters are weak indicating thereby, that this character effects yield more directly than indirectly. Devendra Singh et al. (1978) reported in wheat that the direct effect of grain number per shoot on yield was more than the direct effect of 1000-grain weight.

Path coefficient analysis in Macaroni wheat by Gupta et al. (1979) indicated that 100-grain weight and number of grains per spike were direct components of grain yield, while grain weight per spike was an indirect component. Larik (1979) observed in mutants of bread wheat that the direct effect of tiller number on grain yield was high and positive whereas the indirect effect via spike length and grain number per spike were negligible. The total correlation coefficient between yield and tiller number was mainly due to direct effects. However, Sip and Skorpik (1979) found that in wheat, number of grains per spikelet, number of ears per plant and 1000-grain

weight had the strongest effect on yield. They also found that the number of spikelets per ear was a very stable varietal characteristics, little affected by environment. Guzhov and Malyuzhenets (1981), in an analysis of number of productive tillers, number of developed spikelets, number of grains per spikelet and 1000-grain weight in one Soviet and one foreign variety of wheat, found that the major effect on grain yield from the main ear was by number of grains per spikelet.

Kumbhar et al. (1981) found in wheat that the direct effect of spike length on grain yield was low and negative. The indirect effect via spikelets and spike yield was positive but very low in magnitude. The direct effects of spikelets per spike and yield per spike on grain yield per plant was positive and non-significant. Kumbhar et al. (1982) found in durum and bread wheat that harvest index exerted maximum positive direct effect on yield per square metre.

Path analysis in bread wheat by Singh (1982) revealed that productive tillers and grains per spike had high positive direct effects on yield, whereas spike length and 1000-grain weight had moderate and low effects, respectively. Plant height showed negative direct effect on yield. Further the studies on indirect effect of productive tillers via grains per spike and vice-versa indicated that keeping other characters constant, an increase in the number of productive tillers and grains per spike would improve the grain yield. However, path for yield and 11 yield related characters in winter bread wheat hybrids by Khangil'Din et al. (1983) indicated that no single character could serve as a basis for selection since

they were all inter-correlated in a complex way. Jizeng (1984) reported in wheat that peduncle size and width of flag leaf positively affected the grain weight, while the number of grains per ear and ear length do not have any effect.

Path analysis in durum wheat by Rascio et al. (1984) showed that the number of grains per ear had the greatest effect on yield. 1000-grain weight did not have much effect on grain yield.

Jatasra and Paroda (1985) studied grain yield per plant and 10 yield related traits in 10 varieties grown in 2 environments. The four traits included viz., synchrony of emergence, synchrony of height, synchrony of grains per ear and synchrony of grain weight per ear, tillers per plant had greatest direct effect on yield, while grain weight per ear, synchrony in height were other important yield components. It is suggested that these three traits be emphasized when breeding for improved yield.

Borghi et al. (1985) found that direct selection for grain yield gave better results than indirect selection for grain yield via harvest index.

Vlakh and Smochek (1986) in a study of many varieties and promising lines under two stand densities (400 and 700 fertile tillers per square metre) concluded that major effect on yield is attributed to number of tillers per square metre, number of plants per square metre and number of developed grains in ears of lateral tillers.

Sarkar et al. (1988) measured the number of effective tillers, number of grains per ear and 1000-grain weight in 16 varieties sown at different dates in 1985 path and correlation coefficients analysis revealed that for the late sown plots contribution to yield was in the order of number of grains per ear, tiller number and 1000-grain weight. In the early and normal sown plots, it was tiller number, grains per ear and 1000-grain weight.

Qian et al. (1989) assessed thirteen agronomic characters in 48 varieties, their path analysis suggested that 1000-grain weight had the most important direct effect on plot yield, followed by plant height, grains per ear and ears per plot. It was concluded that increased 1000-grain weight decreased plant height and a stable number of grains per ear and ears per plot were the factors contributing most to the increase in yields.

Collaku (1989) in his study emphasized on 1000-grain weight as the main yield component, which accounted for 28.2% of variation in yield, number of spikelets per ear accounting 5 per cent of variation was also important. It is thought that indirect selection for grain yield on the basis of these characters could be effective. The data on partial regression coefficients of Rauth et al. (1989) indicated that the grain yield was mainly dependent on productive tillers per plant, spikelets per spike, grains per spike and 1000-grain weight. A selection index consisting of these characters and grain yield gave a highest relative efficiency (183.8%) compared to selection for grain yield alone.

Dechev (1990) in his path analysis of yield components in durum wheat found that the character with greatest breeding value was grain weight per ear. It showed a close correlation consistent over generations and years with grain yield per plant. Number of ears per plant also appeared important in breeding for yield. Deshmukh et al. (1990) in their study showed that 1000-grain weight, harvest index, tiller number per ear and biomass/m² made the greatest contribution to yield under rainfed condition and grain weight per ear, ear length and biomass/m² under irrigation condition.

Iqbal Singh et al. (1990) reported that total biomass provided the highest consistent direct and indirect effect on grain yield and increased through an increase in number of tillers and in number of grains per ear. Therefore, total biomass was suggested to be the main selection parameter in breeding dryland wheat varieties. Path coefficient analysis of Lungu et al. (1990) identified tillers per plant and grain yield per spike as having strong direct effect on single plant yield. It was suggested that harvest index of individual plants can be used as indirect selection criterion for yield.

2.3 Estimates of heritability and genetic advance

Consistency of the performance of selection in succeeding generations depends upon the magnitude of heritable variation present in the selection to the observed variation. Heritability measures the degree of resemblance between relatives and correspondence between phenotypic value and breeding value.

Lush (1940) described heritability in the 'broad sense' as the proportion of genetic to total or phenotypic variation, and in the 'narrow sense' as the ratio of fixable genetic variability to the total variation. The estimates of heritability in a broad sense are considered to be crude in the sense that the additive (fixable) and epistatic (non-fixable) effects are clubbed together and this may give an over-estimate of the success of phenotypic selection.

The expected genetic progress in a single generation is the heritability fraction of the selection differential (Robinson et al., 1949). A knowledge of the genetic advance to be expected by applying selection pressure to a segregating population is useful in an effective breeding programme. The genetic gain depends on (i) the amount of genetic variability, (ii) the magnitude of masking effect of environment on the genetic diversity, and (iii) the intensity of selection (Comstock and Robinson, 1952).

Heritability and genetic advance both are components of direct selection, it is necessary to utilise heritability estimates in conjunction with selection differential which indicate the expected genetic gain.

Anwar and Chowdary (1969) reported narrow sense heritability estimates smaller than the corresponding broad sense values in all crosses for plant height, heading date and grain yield. Virk et al. (1971) studied nine characters in all varieties and nine derived F_2 hybrids. Plant height, number of days to flowering, number of spikelets per spike and 1000-grain weight had the highest estimates of heritability in the broad sense. Estimates of heritability in narrow sense were lower than those for the broad sense for grain yield, 100-grain weight, days to flowering and spike length indicating the influence of dominance and/or epistasis. It is concluded that number of grains per spike and number of spikelets per spike are two components which would be considerable in selecting parents.

Reiter and Leontev (1972) have shown that the coefficient of heritability of grain number per ear, grain size, grain weight per ear is considerably higher than that of productive tillers and grain weight per plant. In all combinations, heritability of length of growing season and plant height was high. The greatest genetic advance in response to unilateral 10% selection can be expected in number of spikelets/ear, grain number per ear, and grain size. Selection for productive tillers and grain weight per plant can give the desired effect only with multilateral and highly intensive selection.

Viswanatha and Kohli (1973) also obtained highest heritability estimates for spikelet number and 1000-kernel weight. Grain weight and 1000-kernel weight showed high heritability associated with the high expected genetic advance and considered most likely to respond to selection.

Nurmanov (1972) commented that the selection was not promising in population with low or negative heritability in the absence of any genetic diversity among biotypes. Selection for short straw in the early generations was effective for hybrid populations with high heritability for dwarfness and in which tallness was dominant.

Kumar et al. (1972) estimated the heritability values using 3 methods from variance components, from intergenerational regression and intergenerational correlation. Heritable values and estimates of genetic advance were high for 100-grain weight but varied in other characters with the method of calculation. Rana et al. (1973) found lowest genotypic variation for the number of days to ear emergence, height and 1000-kernel weight, plant height and number of days for heading and ear length had high estimated heritability. The number of grains per ear, yield per plant and number of tillers per plant had low estimated heritability and estimated genetic gain was highest in number of tillers per plant and 1000-grain weight.

Hraska (1973) obtained in highly heterotic combinations, the coefficients of heritability for the quantitative characters lower than in any for the hybrids. Mariani and Zitelli (1973) studied the F_2 data from crosses of durum wheat which carry dwarfing genes derived from Norin-10 with varieties of normal or intermediate height were analysed. The highest heritability found was for plant height (over 90% average) and peduncle length (83%) which are controlled by a small number of genes possibly same for both features. Ear length showed a mean heritability of 56%, heritability for grains per ear

exceeded 90% in some combinations. These indications of the possibility of breeding dwarf forms of durum wheats with high yield have been confirmed experimentally using the same initial material.

Salim et al. (1975) reported that the heritability was high for all characters in crosses involving the semidwarf varieties (Sonora-64 and Myo-54), but length of the spike and of upper four leaves had noticeably lower heritability estimates than other characters. Perwez and Haque (1975) found that the weight of grains per ear and 1000-grain weight gave high broadsense heritability estimates and genetic advance indicating that high heritability estimates for these characters are mainly due to additive effects, phenotypic selection for height, grains per ear and 1000-grain weight should be effective in the F_2 populations of both the crosses studied.

Sharma et al. (1975), studied in the parental, F_2 and F_3 generations of two crosses and their reciprocals involving three varieties in all, heritability estimates based on regression coefficient provided a clear differentiation of the heritability of 1000-kernel weight than those based on variance with heritability reaching 53% at its highest in K-65 x Kalyansona, but its lowest value 25% in the reciprocal cross. The total genetic variability was high indicating that early selection for 1000-grain weight would be effective. The heritability values for protein content based on variables were upto 9 times as great as obtained from regression coefficients. Transgressive segregation for high protein content occurred in

particular F_2 plants.

Maloo (1984) tabulated pooled data on mean, range and genetic coefficient of variation, heritability and genetic advance for yield and 7 of its components in 36 F_1 crosses involving 9 parents. Genetic advance was high for yield per plant, effective tiller per plant, 1000-kernel weight, plant height and spike length.

Gharzai (1985) analysed the data from the F_1 - F_5 of four crosses involving 4 high protein and two moderately low protein cultivars and revealed that heritability estimates which were generally low and variable between generations, were higher for grain protein content than grain yield. For grain protein content additive and additive x additive gene effects were significant in low x high protein crosses and additive gene effects were significant in high x high protein crosses.

Sharma et al. (1988) found high heritability and genetic advance values for harvest index. Additive gene effects were thought to be important in the inheritance of grain yields, biological yields and harvest index. Pawar et al. (1988) reported that tillers per plant showed the highest genotypic coefficients of variation (GCV) followed by grain yield per plant and plant height. Estimates of both GCV and phenotypic coefficients of variation (PCV) were lowest for grains per ear. Differences between PCV and GCV were high to tillers per plant and ear length indicating environmental effects. Heritability estimates for grain yield per plant, plant height, days to flowering, spikelets per ear, 1000-grain weight and grains per

ear were high.

Li (1989) in a field trial, 10 agronomic characters were assessed in 20 genotypes. Broadsense heritability estimates were highest (91.1%) for the length of the first internode under the spike, followed by those for fertile spikelets number (90%) and plant height (86.4%). Auang et al. (1989) reported that the length of main ear and grain weight per ear had high heritabilities and were connected with grain weight per plant indicating their usefulness as selection criterion.

Pawar et al. (1989) in their studies of heritability and genetic advance in three wheat populations found that heritability values for plant height, days to heading and 1000-grain weight were higher than those for number of tillers per plant, number of grains per plant and grain yield per plant. They also found that genetic advance values were higher for all above traits.

Li (1990) reported that protein content had a relatively low heritability, while high heritability showed by sedimentation value.

2.4 Quality Studies

With the introduction of high yielding Mexican dwarf varieties, systematic breeding efforts were made in India to develop high yielding varieties. As a result of this several varieties which were markedly superior to the older ones for yield were developed and released for commercial cultivation. The new varieties developed in general showed higher protein levels because of their positive response to high nitrogen levels. Systematic efforts should now be intensified to upgrade Indian wheats not only for high protein content but also for superior nutritional quality attributes. Diversification of wheat based products necessitate the developments of suitable varieties for specific end-uses such as for making chapati, bread, cakes, biscuits, etc.

Guntharrrd and McGinnis (1957) showed the high protein samples obtained by high levels of N (120N) contained by high levels of N (120N) contained significantly less lysine than the low protein lines obtained by 40N treatment. The lower lysine arose when nitrogen applications were as late as the boot, flowering or milk stage of growth. The lysine content appeared to vary with the ear or yield or both. Other changes on the amino acid composition were not statistically significant. Large differences in protein content were produced by nitrogen fertilization, but only slight differences in proportional amino acid composition were not statistically significant. Large differences in protein content was produced by nitrogen fertilization, but only

slight difference in proportional amino acid content of total crude proteins. Larson and Nielsen (1966) reported that increasing applications of nitrogen to wheat caused an increase amino acid nitrogen and also total nitrogen to glutamic acid from 15.6 to 17.4. The protein increased from 6.4 to 7.8 in grain and decreased in the lysine from 3.6 to 2.6 and arginine from 11.25 to 9.0.

Singh and Prasad (1966) observed that an increasing trend for yield and protein content by increasing the nitrogen levels. Ewald and Wenzel (1967) examined the effect of nitrogen fertilization and loamy soil, on protein composition and amino acid content in opal summer wheat. Nitrogen fertilization increased the yield, first at higher rate, than at lower rate, grain protein increased by increased levels of nitrogen fertilization from 9.6 to 10.6 per cent with nitrogen fertilization, the major increase was being in glutamic acid, lysine showed no change.

Pereira (1963) reported the variations in the protein content in the grain of 13 varieties of wheat grown in 10 localities in Portugal. Protein content varied more within the same variety grown in different locations than between varieties grown in the same locality. The lysine in the protein varied inversely with protein content.

Gandhi and Nathawat (1968) conducted experiments with six Indian and 14 wheats from overseas grown at two locations under similar conditions and with 3 levels of nitrogen (67.2 kg, 134.5 kg, 201.7 kg/ha). In all the varieties, the percentage of crude gluten varied directly with the percentage of crude

protein. Kernel hardness was inversely related to gluten and seed weight. Varietal differences were highly significant in general higher doses of nitrogen increased protein and gluten content in the grains and decreased the hardness of the kernel but some varieties showed a decrease in protein content, when fertilizer levels were raised above 134.5 kg; others showed an increase only at the highest fertilizer level. The mean protein ranged from 12.0 per cent for lowest to 12.4 per cent for the medium to 13.1 per cent for the highest level of fertilization. The optimum N treatment for the eight varieties of winter wheat investigated was 120 kg/ha by Primost (1968).

Galimov (1969) reported that application of nitrogen caused an increase in protein percentage and absolute content of protein and gluten in bread wheat. The accumulation of protein was better in durum wheat. According to Swaminathan et al. (1969) the lowest protein 11.7 per cent was recorded in S-308 (Sonalika) at Bijnor, a low rainfall area with a sandy soil and the highest value of 18.29 per cent in C-237, a local tall wheat grown at Bhind on clay soil. The lysine content was also influenced by location. Swaminathan et al. (1969) observed as the increased level of nitrogen fertilizers (0, 40, 80, 120, 160 and 200 kg/ha) were applied to six varieties of wheat, the protein content was also increased from 13.7 per cent (0,N) to 16.9 per cent (200 kg/ha). They reported that foliar spray of urea and parqzate, individually and in combination increased the protein content. The nitrogen fertilizer largely affects the protein and other quality characters.

Ermolay (1970) studied the effect of the date of sowing, the time of sowing and the level of fertilizations on the properties of wheat grown over four years in Bulgaria. The amount of crude protein and dry gluten in flour was most affected by level of fertilization. The biggest effect was obtained with 140 kg/ha where the yield of grain was doubled. Total crude protein increased by 19 per cent and dry gluten by 44.3 per cent compared to control.

Many workers reported the positive effects of various levels of 'N' fertilizers on the yield and protein content in wheat (Abrol et al., 1971; Rinno and Ebert, 1972; Laopirojana et al., 1972; Dubetz, 1972; Johnson and Mattern, 1972; and Johnson et al., 1973).

Austin (1970) surveyed improved Indian and Mexican dwarf wheats for protein content. The mean protein content for location varied from 10.5 (range 9.2 to 11.6%) at Janpur to 16.4% (range 14.5-17.7) at Bardoli. There were marked effects with location in protein content of the grain. The highest protein content was observed in Mexican dwarf wheats e.g. Sonora-64, 14.2 per cent; Lerma Rojo, 13.8 per cent; Sonora-63, 13.7 per cent.

The influence of location and genotype on protein, lysine and grain yield in wheat and triticale was reported by many workers (McNeal et al., 1972; Ruckman et al., 1972; Pokrovskaya, 1973).

Borghi et al. (1975) studied ten wheat varieties grown at 4 locations. The protein content ranged from 12.7 to 16 per cent and IBO 40-618 had the highest baking quality. G x E

interactions were significant for sedimentation value, hecto-litre weight, grain yield and 1000-kernel weight.

Srivastava et al. (1971) studied the protein and amino acid composition of sample of wheat grown under rainfed condition showing the highest protein percentage (10.43%) was obtained at 80 kg/ha (applied in soil + foliar) when compared with 7.23 per cent of protein at 0 kg N/ha. Lysine percentage in the protein was inversely correlated with total protein in the wheat. Panwar et al. (1971) reported that the application of nitrogen half through soil and half through foliar spray, gave 5.8 per cent higher yields. The protein content was maximum (14.9 %), when the entire dose of N was applied as foliar.

Sosulski^{et al} (1963) found the reduced water supply, nitrogen fertilization and higher air temperature increased the protein content of Thatcher wheat, grown under controlled environmental conditions exerted the greater effect on protein content, while the largest responses to N, fertilization were obtained at medium moisture level protein content ranged from 10.2 per cent to 23.0⁴ per cent for the samples grown at 3 moisture regime and 5 fertility levels. Lysine was negatively correlated with protein content.

Frankel Conrat Cooper (1944) used a dye binding method to determine the number of different groups of several proteins and protein fractions. Since these groups mainly originate from the basic amino acids, histidine, arginine, and lysine. Udy (1954, 1956) used this principle to estimate crude protein

in wheat, with the assumption that the proteins are distributed in regular manner in the varieties, and the proportion of basic amino acids is reasonably constant.

Mossberg (1969) reported a correlation of $+0.767$ between DBC and nitrogen content in wheat. Sharma and Kaul (1971) also reported high correlation coefficient values between DBC and protein values, obtained by Micro and Macro Kjeldahl methods. Lately, the DBC method has been taken up as a standard method for estimation of nitrogen as well as basic amino acids in the leading laboratories for crop protein improvement all over the world. Mossberg (1969) reported correlation coefficient value of $+0.94$ between DBC values and basic amino acids in wheat. This method was extensively used in barley germplasm in identifying Hiproly (CI 3947) which contains both high protein and lysine by Munk et al. (1970).

Kaul (1973) has suggested the usefulness of this technique in selecting high protein (of good quality) high yielding lines in the quality breeding material. Sodek and Wilson (1971), Mertz et al. (1973) reported that the endosperm of Opaque-2 maize had a higher level of water soluble free amino acids than normal maize varieties. Mertz et al. (1973) reported the free amino acids in different crops. High lysine mutants of maize, sorghum, barley contain 3 to 4 times more water soluble free amino acids than the normal counterparts, rice, millets and oats has the value in the range of normal maize, sorghum and barley, wheat has slightly higher values.

Jain et al. (1976) analysed that there is a significant positive correlation between seed size and the protein content

of seeds. It further shows that for unit increase in seed weight, the starch content shows relatively larger increase than the protein content.

Singhal and Jain (1981) found out that seed weight can be an important phenotypic marker in selecting for high protein genotypes in bread wheat.

Brunori et al. (1982) reported that nitrogen per cent and seed weight were not correlated. High nitrogen amounts per grain resulted always from the combination of larger grain and high nitrogen percentage.

Brunori et al. (1983) found that the variability among genotypes for pattern of nitrogen accumulation in developing grain of Triticum aestivum has indicated the existence of various genes controlling the process of protein accumulation. They have reported that pattern of kinetics and amount of nitrogen per grains can apparently be transferred in cross breeding. Analysis of F_7 lines has shown that Pusa 5-3 and 'F26-70' are actually more effective high protein donors than 'Atlas 66'. Several high yielding, high protein lines with reduced plant height were found in the progenies from Pusa 5-3 and 'F26-70' but not among the derivatives of 'Atlas-66'.

Fedin (1983) in an analysis of data from a 6x6 diallele cross indicated the predominance of additive gene effects in the control of protein content, with low content tending to dominate over high. Kirichenko (1984) in a study of F_1 - F_2 hybrids of ten high protein varieties with high yielding varieties, the F_1 s were generally intermediate between their

parents in protein content and close to the worse parent. Segregation in the F_2 depended on the genotype of the parents. The best sources of high protein content were 'Atlas-66', Dunav NS-60 and Iohardi.

Bebyakin and Martynov (1984) in a study of 26 families of different quality randomly selected in the F_3 from F_1 (Atlas-66 x Diamant) x Saratovskaya 38 and grown in F_4 - F_5 , the genotypic correlations were determined between grain quality characters and between these and loaf volume. In dry years, a negative correlation was found between loaf volume and both protein content of grain and gluten content of flour.

Gharzai (1985) analysed the data from F_1 - F_5 of four crosses involving four high protein and two moderately low protein cultivars, which revealed that frequencies for grain protein content, grain yield, number of grains per plant, 100-grain weight, number of spikes per plant and number of grains per spike had normal distribution curves, suggesting quantitative inheritance of these traits. Heritability estimates which were generally low and variable between generations, were higher for grain protein content than for grain yield. For grain protein content, additive and additive x additive gene effects were significant.

Kostic (1987) in his study on dynamics of nitrogen revealed that grain yield mostly depended on nitrogen content of plant in heading. Positive correlation occurred between nitrogen content in top leaf, ear, stalk + sheath and the quality (total nitrogen content in grain).

Mahdy (1988) reported that genotypic correlation was

negative between grain protein per cent and each of grain yield per plant ($r=-0.88$), spike per plant (-0.92) and 1000-grain weight (-0.80 and was positive for heading date 0.66) and plant height.

Barrett et al. (1989) found that cultivar x environmental effects were highly significant. G x E interactions were small but significant. Among variance components, ears contributed most to total variance for protein and sediment value. Inter-genotypic differences in grain yield and grain weight were correlated with all quality traits. Lin (1989) reported a negative correlation between grain yield and protein content, protein content showed a positive correlation with wet gluten content and sedimentation value. Zhang et al. (1989) reported that grain protein content was more highly correlated with yield components than with other traits but were most highly correlated with amino acid content, protein variation caused by yield components, physiological and morphological characteristics was 44.5, 31.7 and 28.9 per cent respectively.

Li (1990) found significant negative correlation between grain protein content and each of grain weight per plant, 1000-grain weight and ear length. He also reported that protein content had a relatively low heritability while higher heritability showed by sedimentation value. Lungu et al. (1990) reported a significant negative relationship between yield and protein content within all generations. Noaman et al. (1990) studied the genotypic and phenotypic correlations between grain protein and vegetative protein and found that there exists a

significant correlation. Estimates of narrow sense heritability of protein content using the variance component method ranged from 0.46 to 0.94 for leaf and head, correlation coefficients (r) between predicted and observed grain protein ranged from 0.50 to 0.88 and from 0.37 to 0.84 in both populations respectively. No significant correlations were observed between protein in plant parts and grain yield.

Stenram et al. (1990) reported that at higher nitrogen fertilization levels there was a negative correlation between grain yield and protein content. During grain development, the gliadin content increased and the albumin content decreased, whereas globulin and glutenin content remained almost constant, gliadin content increased rapidly when crop was supplied with high amount of nitrogen fertilizers. Vierling and Nguyen (1990) studied Heat Shock Protein (HSP) synthesis and accumulation in diploid wheat, these are synthesised under high temperature stress, playing role in genetic control of thermal tolerance in plants. Results showed that qualitative and quantitative diversity of HSP synthesis and accumulation.

Peterson et al. (1992) in their studies of genotype and environment effects on quality characteristics in winter wheat it was found that these effects were significantly influence variation in all quality parameters. Variances of quality characteristics with environmental effects were gradually larger than those for genetic factors.

3. MATERIAL AND METHODS

The experimental material consisted of twenty-five genotypes categorised under three groups (early, medium and late) with variable protein content. The genotypes under early maturing group were P38-15 P117-1, P117-3, P118-2, KLM3-5, KLM-26 (strains) and HD-2285 (cultivar), the medium maturing group P-102, P-108, P-577, P-608, P-642, P-766, P-925, Pusa 5-3 (strains), NP-4, NP-880 and HD-2160 (old cultivars), HD-2329, HD-2428 (cultivars) and the late maturing group P-932, P-1035, P-1142, P-1312 (strains) and C-306 (cultivar). The basis for classifying the strains and cultivars is the number of days for flowering after sowing. The strains and cultivars which flowered before eighty days after sowing were grouped into early maturity group, like wise which flowered between eighty and ninety days were grouped into medium maturity group and the strains and cultivars which flowered later than ninety days were grouped into late maturing group. These strains used in our study were the outcome of breeding for the improvement of nutritional quality in wheat.

These studies were undertaken to evaluate the newly developed strains in comparison to the high yielding cultivars. The experiment was conducted in RBD with three replications with individual plot size measuring five metres length with six rows of twenty-three centimetres apart for each genotype. The recommended fertilizer dose of 60P and 40K was applied and irrigation was given according to the schedule. However, for yield consideration square metre harvest was obtained for

computing harvest index for obvious reasons. The effective tiller number per unit area were counted for square metre area.

Protein accumulation studies were undertaken by collecting ear head samples with developing grains at one week interval, after fifteen days of flowering. The samples were collected from central four rows to avoid border effects. The collected samples were dried and preserved for protein estimation.

Observations on various morphological characters which contribute towards the grain productivity were recorded. Five randomly selected plants were taken to study some of the yield component characters mentioned below.

3.1 Observations recorded

3.1.1 Tiller number per square metre: The number of ear bearing tillers per square metre area at maturity stage was counted for each strain/variety.

3.1.2 Plant height: The plant height was measured in centimetres from the base of the plant to the tip of the main spike at maturity stage.

3.1.3 Dry weight of the tillers (kg/m^2): The total plants harvested in a square metre area were sundried including spikes and weighed to get the dry weight of the tillers.

3.1.4 Days to flower: The number of days to flowering was computed from the sowing date to 50 per cent of flower emergence in each plot.

3.1.5 Grain yield (kg/m^2): The plants harvested from square metre area were threshed and grains weighed.

3.1.6 Harvest index (%): It is a proportion of grain yield to the total dry matter production in percentage.

3.1.7 Spike length (cm): The main spike was collected from each plant for further observations. The length of the spike was measured in centimetres from base to tip excluding the awns. Five spikes were collected and average value was taken.

3.1.8 Grain number per spike: After threshing the individual spike, the number of grains per spike were counted.

3.1.9 Grain weight per spike (gm): Seeds obtained from individual spike were weighed on single pan electrical balance.

3.1.10 1000-grain weight: This was computed on the basis of 200-seeds counted at random.

3.1.11 Protein content (%): The percentage of protein in the harvest sample of grains was obtained by the Kjeltac Auto Analyser.

3.1.12 Protein yield per square metre (gm/m^2): This parameter was obtained by multiplying grain yield per square metre with protein per cent.

3.1.13 Protein per grain (mg): This is the proportion of protein present in each grain on dry weight basis. This was obtained by multiplying the protein per cent by individual grain weight.

The parentage of these strains and description of wheat cultivars included in this investigation are given below.

3.2.1 Advanced generation fixed strains

S.No.	Name of the strain	Parentage
1.	P38-15	(5-3 x HD 1982) x 566-1-3
2.	P117-1	S-3 x HD 1982
3.	P117-3	S-3 x HD 1982
4.	P118-2	S-3 x HD 1982
5.	KLM 3-5	Mutant selection from Kharchia Local
6.	KLM-26	_____do_____
7.	P 102	T-2487-4 Tanori Mutant
8.	P 108	(Raj-911 x S-3) x 5-3-65
9.	P 577	WL 711 x CPAN 1695
10.	P 608	WL 711 x CPAN 1695
11.	P 642	WL 711 x CPAN 1695
12.	P 766	WL 711 x LR 24
13.	P 925	WL 711 x LR 24
14.	P 932	WL 711 x LR 24
15.	P 1035	LR 24 x Kalyansona
16.	P 1142	LR 24 x Kalyansona
17.	P 1312	LR 24 x Kalyansona
18.	Pusa 5-3	HW 171 x CI 11721

3.2.2 Cultivars

3.2.2.1. HD 2329: This variety developed from a complex cross (HD 1962-E4870-K65 x HD-15153)/UP 362 is a double dwarf and medium early maturing with profuse and synchronous tillering

habit. Spikes are fusiform, fully bearded, mid-dense with dark and brown non-hairy glumes. Grains are amber, hard, medium bold and lustrous, it possesses good chapati and bread making qualities.

3.2.2.2 HD 2428: Developed from the cross HD 1949 (Mote) x HD 2160, it is a triple dwarf (D_3^+ height) with amber, medium bold and semihard grain, suitable for high fertility irrigated timely sown conditions of northern plains zone.

3.2.2.3 HD 2285: It is a double dwarf variety developed by a cross 249/HD2160//HD2160, for high fertility and late sown conditions. It is an early maturing variety when compared to Sonalika and has also got high yielding potential than Sonalika.

3.2.2.4 HD 2160: It is a triple gene dwarf variety derived from MZ*3//YT54/N 10B/3/CAL/4/TOB/CTFN/5/HD 1949 with profuse tillering and white glumes. It is a high yielding variety awned, resistant to all three rusts and a good combiner.

3.2.2.5 C-306: It has been derived from RG/CSK3//2* C591/3/C-216/NI 4//C 281. It is a tall growing variety fully bearded with hairy glumes which turn white on maturity. This variety has a good tillering capacity. It has bold, hard and amber grains. It is recommended for rainfed conditions.

3.2.2.6 NP-4 : It is a pureline selection from local sort Mundya (means awnless), tall, awnless with white and hairy glumes, released for cultivation in Northern Plains Zone.

3.3 Statistical Analysis

3.3.1 Analysis of Variance

Analysis of variance was carried out on the basis of

randomised block design as described by Panse and Sukhatme (1985).

3.3.2 Estimation of mean, range, standard deviation and critical difference

Mean value of each character was worked out by dividing the totals by corresponding number of observations while the lowest and highest values for each character was taken as range. Standard error of mean and critical difference were calculated as follows:

$$\text{S.E. of mean (SEM)} = \sqrt{\frac{\text{EMS}}{r}}$$

$$\text{c.d. (at 5\%)} = \sqrt{2 \frac{\text{EMS}}{r}} \times \text{'t' value at error df at 5\% level of significance.}$$

Where, r= number of replications

EMS= Error mean square.

3.3.3 Genotypic, phenotypic and environmental correlation coefficients

a) Phenotypic correlation coefficients

$$r_p = \frac{\text{Cov. (xy)}}{\sigma_x \times \sigma_y}$$

b) Environmental correlation coefficients

$$r_e = \frac{\text{Cov. (xy)}}{\sigma_x \times \sigma_y}$$

where, x and y present two characters.

b = number of blocks or replications.

σ_{xy}^2 = expected mean product between X and Y

p = number of progenies

σ_x^2 = expected mean squares for x^{th} character.

The significance of phenotypic correlation coefficients was tested against 'r' values from 't' table of Fisher and Yates (1957) for $(v-2)$ degrees of freedom and for environmental correlation coefficients $(n-2)$ degrees of freedom at $p = 0.55$ where 'v' is the number of varieties and 'n' is the number of independent comparisons.

Similarly, correlation coefficients of genotypic level were worked out using the respective covariances and variances.

3.3.4 Path analysis

Path analysis was done as per Dewey and Lu (1959) and Ramanujam and Rai (1963) to assess direct and indirect influences of various components on grain yield.

Path coefficient can be defined as the ratio of the standard deviation of the effect due to given cause to the total standard deviation of effect i.f. if yield (y) is the function or effect and X_1 (one of the various components or causal factor of yield), the path coefficient for the path from cause X_1 to the effect 'y' is σ_{X_1} / σ_Y .

The path coefficients were obtained by solving a set of simultaneous equations of the form-

$$r_{ny} = P_{ny} + r_{n2}P_{2y} + r_{n3}P_{3y} \dots\dots\dots$$

where, r_{ny} = correlation between n^{th} component character and yield;

P_{ny} = path coefficient between the n^{th} character and the yield;

and r_{n2}, r_{n3} etc. stand for correlation between that character and each of the other yield components in turn.

$n = 1, 2, \dots, n$ i.e. various causal factors.

Considering all the simultaneous equations, correlation matrices of the following were prepared.

$$\begin{array}{ccc} \left[\begin{array}{c} \text{Matrix 'A'} \\ r_{1y} \\ r_{2y} \\ \vdots \\ r_{ny} \end{array} \right] & = & \left[\begin{array}{cccc} & \text{Matrix 'B'} & & \\ 1 & r_{12} & r_{13} & \dots\dots r_{1n} \\ r_{21} & 1 & r_{23} & \dots\dots r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & r_{n3} & \dots\dots 1 \end{array} \right] \left[\begin{array}{c} \text{Matrix } P_{iy} \\ P_{1y} \\ P_{2y} \\ \vdots \\ P_{ny} \end{array} \right] \\ n \times 1 & & n \times n \qquad \qquad n \times 1 \end{array}$$

Such that $A = (B) \times (P_{iy})$

The solution for the vector (P_{iy}) (path coefficient) was obtained by multiplying both sides by inverse of 'B' matrix i.e. B^{-1} thus

$$P_{iy} = (B^{-1}) \times (A)$$

The indirect effect for a particular character through other characters were obtained by multiplication of direct path and particular correlation coefficients between those characters respectively.

Indirect effect of j^{th} character through i^{th}

$$i^{\text{th}} = r_{ij} \times P_{iy} \text{ where } i=1\dots 11; j=1\dots 11 \text{ and}$$

$$P_{iy} = P_{1y}P_{2y} \dots\dots\dots P_{ny}$$

The undefined factor i.e. the variation in yield unaccounted for causal effects is under consideration were designated by 'X'. The path value for residual (X) was calculated in the following way:

$$\text{Residual factor (X)} = 1 - R^2$$

$$R^2 = \sum P_{iy}^2 + \sum_i \sum_j P_i P_j r_{ij} \quad (i \neq j)$$

where, P_{iy} = Path from i^{th} character to yield

r_{ij} = Correlation between i^{th} and j^{th} independent character.

R^2 is the squared multiple correlation coefficient and is the amount of variation in yield that can be accounted for by the yield component characters.

3.3.5 Estimation of heritability (Broadsense)

Heritable variation i.e. the fraction of genetic variation to the total variation was computed from the table of analysis of variance by the following formula:

$$h^2_b = \frac{\sigma_g^2}{\sigma_g^2 + \sigma_e^2}$$

where $\hat{\sigma}_e^2$ = error variances and $\hat{\sigma}_g^2$ = genetic variance estimated from ANOVA Table.

3.3.6 Expected genetic advance

The expected genetic advance from straight selection $G(s)$ was computed according to the following formula suggested by Robinson, Comstock and Harvey (1949).

$$G(s) = K \cdot h^2 \sigma_p$$

where, K = Selection differential units which is =2.06 for 5% selection intensity.

h^2 = heritability in broadsense, and

σ_p = phenotypic standard deviation.

3.3.7 Genotypic and phenotypic coefficient of variation

The genotypic (GCV) and phenotypic (PCV) coefficients of variation were calculated by the formula given by Burton (1952).

$$GCV (\%) = \frac{\text{Genotypic standard deviation } (\sqrt{\hat{\sigma}_g^2})}{\text{Grand mean}} \times 100$$

$$PCV (\%) = \frac{\text{Phenotypic standard deviation } (\sqrt{\hat{\sigma}_p^2})}{\text{Grand mean}} \times 100$$

3.4 Chemical procedures

3.4.1. Determination of protein content

3.4.1.1 Reagents

- 1) H_2SO_4 : 1:100 Orthophosphoric acid and concentrated H_2SO_4 .

- 2) Catalyst : 500 gms of K_2SO_4 + 10 gm of Cupric sulphate.
- 3) a. Alkali: NaOH 40% (b) Boric Acid (4%)
- 4) Mixed indicator:
 - a. 0.5 g of Bromocresol green dissolved in 100 ml of methyl alcohol.
 - b. 0.1 g of methyl red dissolved in 100 ml of methyl alcohol and mixed (a) and (b).
- 5) 0.1 N-HCl: 8.7 ml of concentrated HCl in one litre distilled water.
- 6) 0.1 N- Na_2CO_3 : 530 g of Na_2CO_3 dissolved in one litre of distilled water.

3.4.1.2. Procedure

a) Digestion: Weighed 0.5 gm of the sample and added 10 ml Conc. H_2SO_4 reagent + 4.5 gms of Catalyst; digested it at $450^\circ C$ for 30-45 minutes till the contents were clear (the colour of the solution will be blue when it is hot and white in cooling). After cooling, added 75 ml of distilled water and shaken thoroughly till the contents are clear.

b) Distillation: The tube digested sample was transferred to the 'Kjeltec Auto Analyser' (an automatic distillation unit) wherein alkali (40 ml) and boric acid (25 ml) to be used are automatically adjusted in each working sample. The ammonia released during distillation is automatically titrated against 0.1 N HCl and the titre value is automatically multiplied with the factor 5.7 (for wheat) before the actual protein content in percentage is displayed on the meter.

4. EXPERIMENTAL RESULTS

The present study was undertaken to evaluate some advanced generation fixed lines in comparison with wheat cultivars for their performance in yield, yield attributes, protein content and nitrogen accumulation. The Statistical analysis work was carried out on the data of both yield related characters and protein content. Data on Nitrogen accumulation was also analysed statistically. The results of the experiments are presented under the following heads:

- 4.1 Analysis of variance
- 4.2 Correlation studies
- 4.3 Path analysis
- 4.4 Studies on heritability and genetic advance
- 4.5 Nitrogen accumulation studies

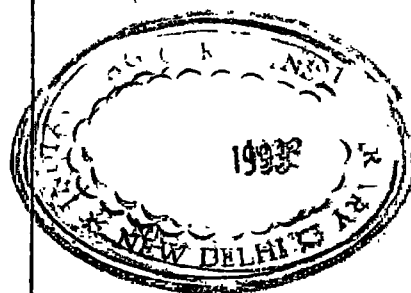
4.1 Analysis of Variance

Analysis of variance was carried out on the basis of results obtained from randomised block design for all the characters under study for the strains and controls together of all three, early, medium and late maturity groups. The results obtained for the analyses of variance were presented in Tables 1 to 4. Tables 1 gives the summary analysis of variance in respect of thirteen characters for eighteen strains and seven controls of all the three maturity groups pooled over three years of study. Separate results of ANOVA calculated for early, medium and late maturity groups were presented in Table 1, 2 and 3 respectively. The comparative grand mean values over

Table 1: Summary of analysis of variance in respect of thirteen characters in eighteen strains and seven controls of all three maturity groups pooled over three years of study

Source of Variation	d.f.	SUM OF SQUARES												
		Tiller number/ m ²	Plant height (cm)	Days to flower	Dry wt. of tillers (kg/m ²)	Grain yield (kg/m ²)	Harvest index (%)	Spike length (cm)	Grain No./ spike	Grain wt./ spike (gm)	1000- grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein /grain (mg)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Year	2	201298.0	1451.3	141.8	4.73	0.067	1113.4	0.758	172.0	0.324	211.8	51.19	1959.1	14.18
Replication	2	7086.0	0.0	0.125	0.091	0.0017	16.88	0.133	5.391	0.017	14.50	1.52	170.6	0.136
Y x R	4	8809.0	12.18	0.312	0.044	0.002	1.87	0.098	41.49	0.059	3.76	0.355	120.0	0.029
Treatment	24	11927.0	1403.0	339.3	0.055	0.022	106.16	2.832	360.9	0.331	152.6	14.94	392.1	7.86
Y x T	48	6017.5	54.96	6.609	0.027	0.006	28.63	0.464	33.80	0.059	12.36	1.96	158.0	0.511
Error	144	2694.3	18.58	0.179	0.011	0.0009	7.21	0.354	12.75	0.029	3.55	0.319	29.18	0.139

*** = Significant at 1% level.



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Table 2: Summary of analysis of variance in respect of thirteen characters in six strains and one control of early maturity group pooled over three years of study

Source of Variation	d.f.	SUM OF SQUARES												
		Tiller No./m ²	Plant height (cm)	Days to flower	Dry wt. of tillers (kg/m ²)	Grain yield (kg/m ²)	Harvest index (%)	Spike length (cm)	Grain No./ spike	Grain wt./ spike (gm)	1000-grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein per grain (mg)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Year	2	89938.5	1040.30	73.000	1.431	0.0230	246.07	1.503	75.62	0.137	129.350	18.74	175.38	3.953
Replli-cation	2	10386.5	0.906	0.047	0.047	0.0008	20.75	0.205	1.511	0.048	11.828	0.73	90.42	0.022
Y x R	4	1298.5	28.52	0.484	0.011	0.0008	3.52	0.018	14.68	0.013	10.764	0.23	36.21	0.0348
Treatment	6	9169.0	139.40	11.619	0.034	0.0063	34.41	1.573	74.19	0.136	51.608	24.47	58.33	6.392
Y x T	12	7399.9	60.23	1.722	0.031	0.0033	25.87	0.893	43.15	0.087	11.167	1.68	122.82	0.519
Error	36	2736.0	17.84	0.425	0.013	0.0013	10.39	0.309	10.25	0.029	4.766	0.288	32.62	0.260

** : Significant at 1% level.

Table 3: Summary of analysis of variance in respect of thirteen characters in eight strains and five controls of medium maturity group pooled over three years of study

Source of Variation	d.f.	SUM OF SQUARES												
		Tiller number/ m ²	Plant height to (cm)	Days flower	Dry wt. of tillers (kg/m ²)	Grain yield (kg/m ²)	Harvest index (%)	Spike length (cm)	Grain No./ spike	Grain weight/ spike (gm)	1000- grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein /grain (mg)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Year	2	105339.0 ^{**}	467.60 ^{**}	99.870 ^{**}	2.270 ^{**}	0.067 ^{**}	627.610 ^{**}	0.333 ^{**}	91.15 ^{**}	0.157 ^{**}	72.720 ^{**}	30.160 ^{**}	1920.80 ^{**}	10.530 ^{**}
Repli- cation	2	2094.0	13.75	0.062	0.034	0.002	0.742	0.075	35.73	0.035	6.520	0.695	165.50	0.088
Y x R	4	7768.0	4.40	0.031	0.013	0.002	1.758	0.335	29.68	0.032	0.359	0.262	90.95	0.797
Treatment	12	13791.8	2153.3	21.14	0.053	0.024	121.97	4.406	123.37	0.225	123.86	10.20	272.70	5.591
Y x T	24	3809.2	39.95	8.66	0.028	0.007	25.15	0.315	42.53	0.059	12.52	2.32	176.34	0.417
Error	72	2563.3	20.60	0.89	0.009	0.0006	6.023	0.369	8.28	0.023	3.06	0.342	22.28	0.095

** : Significant at 1% level.

Table 4: Summary of analysis of variance in respect of thirteen characters in four strains and one control of late maturity group pooled over three years of study

Source of Variation d.f.		SUM OF SQUARES												
		Tiller number/ m ²	Plant height (cm)	Days to flower	Dry wt. of tillers (kg/m ²)	Grain yield (kg/m ²)	Harvest index (%)	Spike length (cm)	Grain number/ spike	Grain weight/ spike (gm)	1000- grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein per grain (mg)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Year	2	25037.3	18.30	6.016	1.044	0.0007	384.1	0.112	20.04	0.061	36.05	5.131	299.8	1.147
Replis cation	2	25.0	20.00	0.078	0.029	0.0005	7.98	0.230	20.71	0.050	0.621	0.186	12.52	0.080
Y x R	4	1540.8	6.030	0.234	0.056	0.0008	6.30	0.279	25.49	0.061	2.64	0.545	54.64	0.069
Treat- ment	4	12374.0	447.5	10.98	0.086	0.0193	89.63	1.429	648.9	0.548	55.37	3.395	641.8	1.848
Y x T	8	8825.1	200.10	1.83	0.026	0.0028	21.41	0.176	6.81	0.037	13.28	1.542	125.8	0.676
Error	24	3622.3	13.80	0.093	0.012	0.0014	6.92	45.2	27.1	0.045	3.09	0.333	40.87	0.076

** = Significant at 1% level.

three years of group-I (strains) and group-II (controls) entries presented in Table 5.

4.1.1 Tiller number per square metre

The results in Tables 1 to 4 reveal highly significant differences among the genotypes. Data on relative mean number of tillers per square metre along with other characters were presented in Appendix-I for all three maturity groups together and separately over three years of study. Highly significant differences exists among the genotypes of early, medium and late maturity groups, over all three years of study. The Year x Treatment interaction for this character, is highly significant, showing varied tillering abilities of genotypes irrespective of their duration of maturity. Tillering ability varied within the same maturity group and between the maturity groups. Though significant differences exists among the genotypes for this character, the group mean for the strains (Group I) was negative but non-significant when compared to the controls (Group II). However, high grand mean values were observed in some strains viz., KLM 3-5 (559.0 tillers/m²), P 38-5 (521.0), P118-2 (514.0) and KLM-26 (501.3) among early maturity group, P-642 (587.3), P-577 (519.3), P-608 (513.3), P-766 (505.0) and P-925 (504.0) among medium maturity group and P-932 (503.0) among late maturing strains. These values are much higher than the controls in each maturity group and much higher than the group mean of the controls together (Appendix-I).

The highest mean tiller number per square metre was found in P-642 (587.3) in medium maturity group followed by KLM 3-5 (559.0) and P 38-15 (521.0) which fall under early maturity

Table 5: Brief summary showing significant differences between the characters of the strains in comparison with controls

Characters	Group mean		C.D. at 5%	G_1-G_2	Remarks
	Strains (G_1)	Controls (G_2)			
1. Tiller number /m ²	432.0	437.7	83.07	-5.71	NS
2. Plant height (cm)	98.12	98.8	6.90	-0.68	NS
3. Days to flower	86.10	84.9	0.68	1.24	S
4. Dry weight of tillers(kg/m ²)	1.36	1.37	0.17	-0.01	NS
5. Grain yield (kg/m ²)	0.4077	0.4157	0.04	-0.008	NS
6. Harvest index (%)	31.45	30.90	4.29	0.55	NS
7. Spike length (cm)	9.96	9.95	0.95	0.01	NS
8. Grain number/spike	44.38	42.28	5.71	2.10	NS
9. Grain weight/spike (gms)	1.67	1.65	0.27	0.02	NS
10. 1000-grain weight (gm)	37.48	38.98	3.02	-1.50	NS
11. Protein content (%)	16.22	14.34	0.90	1.88	S
12. Protein yield (g/m ²)	66.7	63.13	8.64	3.57	NS
13. Protein per grain (mg)	6.08	6.04	0.59	0.04	NS

S: Significant

NS: Non-significant

group. The lowest mean was observed in KLM-26 (317.3) of early maturity group. It showed that the strain P-642 have given highest mean tillers per square metre than the best control.

4.1.2 Plant height (cm)

Analysis of variance for plant height revealed significant differences among all the genotypes of all three maturity groups. Almost all the strains used in this investigation were double gene dwarfs having desirable plant types. However, the group mean for strains (98.12) was slightly less than that of group mean of controls (98.8). The standard Check varieties included in this experiment were HD 2160 and HD 2428 gave low values for plant height i.e. 63.8 cms and 76.4 cms respectively. The highest mean values for this character was shown by NP 850 (126.7 cm) followed by NP-4 (116.1). The lowest mean values were found in strain P38-15 (90.0 cm) followed by P118-2 (94.4 cm) belonging to early maturity group.

4.1.3 Days to flower

The strains and varieties included in this experiment were of three different maturity groups, classified on the basis of flowering duration. The genotypes flowering earlier than 80 days were grouped in early maturity group, those flowering between 80 and 90 days were grouped in medium maturity group and above 90 days duration of flowering were placed in late maturity group. Significant genotypic differences were observed among all the strains and controls for this character. The group mean values for strains were found to be higher and significant than controls, showing their earliness in dates of flowering. Among the early maturity group, the strains P117-3

(74.3 days) and P 38-15 (75.3 days) were found to be slightly early in flowering than the control HD 2285 (75.8), whereas the other strains P117-1 (76.3), P118-2 (76.7), KLM 3-5 (77.4) and KLM-26 (77.4) were flowered slightly later than the control. Among the medium maturity group Pusa 5-3 (83.3) and P-108 (84.3) flowered earlier than the control HD 2428 (84.0). Among late maturity group, P-932 (91.6) was found to flower earlier than the control C.306 (92.0).

4.1.4 Dry matter production per square metre

Analysis of variance for biomass production per square metre also showed highly significant differences among the genotypes of all three maturity groups, whereas the results did not show much difference for all three years of study. The sum of square values for pooled analysis were much higher than the individual year. The Year x Treatment interaction values did not show much differences over years. However, the group mean values for strains (1.36) was found to be at par with the controls (1.37). The mean biomass production ranged from 1.23 kg/m² (P117-3) to 1.48 kg/m² (P-925). The mean values for early, medium and late maturity groups were 1.32, 1.37 and 1.39, respectively. It showed that biomass accumulation was high in late maturity group followed by medium maturity group and early maturity group. However, the grand mean value for both strains and controls over years was 1.36. Dry matter production also varied over the years. The grand mean values for this character for first year of study was higher (1.65) than second year (1.18) and third year (1.25) of study indicating inconsistency and influence of other external

factors in determining the dry matter production.

4.1.5 Grain yield per square metre

Highly significant differences were observed among the genotypes of all three maturity groups for grain yield per square metre. The group mean for strains was found to be at par with the controls showing non-significant difference between strains and controls for their yielding ability. The higher mean values for grain yield was found in the cultivar HD-2428 (0.53 kg/m^2 mean of three years) followed by P-642 (0.48) and P-108 (0.48). However, in the first year of study, P-108 outyielded the control. The mean values of grain yield over three years of study, were 0.44, 0.48 and 0.42, respectively. The grand mean value over years was 0.41 and the grain yielding ability of the genotypes differed slightly with years. The mean value for grain yield for early, medium and late maturity groups were 0.39, 0.43 and 0.38 respectively. It showed that medium maturity group fared well in all three years of study in this aspect when compared to other two maturity groups. Among the late maturity group none of the strains and controls found to be as efficient as the strain of late maturity group P-932 (0.46 kg/m^2 mean of three years) in its yielding ability. It outyielded over all strains and controls in this group over entire three years of study.

4.1.6 Harvest index

Analysis of variance showed, significant differences among the genotypes of all three maturity groups, for this character. The group mean of harvest index for the strains was observed high but nonsignificant in comparison to the controls. The

grand mean value over three years pooled was 31.3 per cent. The harvest index values for early, medium and late maturity groups were 30.6%, 32.6% and 28.8% respectively, showing superior values for medium maturity group. These values were higher for third year (34.5%) than first (27.0%) and second year (32.4%) of study.

The highest grand mean value for this character among the strains was observed in the strain P-108 (37.9%) followed by P-642 (36.5%) and among the controls, superior value was shown by the cultivar HD 2428 (37.4) followed by HD 2329 (34.7), HD 2160 (34.6) and the lowest values were found in NP-850 (24.8) and C-306 (25.0%). Again the highest mean harvest index value was observed in strain P-108 (48.0) in third year of study.

4.1.7 Spike length

Significant genotypic differences exists for this character in all maturity groups. The group mean value for spike length in the strains was slightly higher but non-significant compared to controls. The grand mean value for this character was 9.96 for strains and controls together over entire three years of study. Spike lengths ranged from 9.16 to 11.34 cms, the lowest being found in strain P-608 (9.16) and the highest in strain P-108 (11.34), both strains falling in medium maturity group. The group means for early, medium and late maturity groups were 10.02, 9.94 and 9.95 respectively. Among the years, highest mean value was found in first year (10.08) followed by third (9.92) and second years (9.89). Among the strains higher values were recorded in strains, KLM-26 (10.59), P-102 (10.57), KLM3-5 (10.56), P-766 (10.36), P-1035

(10.32), P-1142 (10.32), P-1312 (10.13) and P-577 (10.00) in addition to the strain P-108 (11.34) which had longest spike among strains. The highest mean value in controls was recorded in cultivar HD-2428 (11.00) followed by HD-2160 (10.04) which are far lower than the strain P-108 (11.34). Most of the late maturity strains showed higher spike lengths than other maturity groups.

4.1.8 Grain number per spike

Analysis of variance revealed highly significant differences among the genotypes of all three maturity groups. The group mean value for strains (44.38) for this character observed was higher than the controls (42.28) but non-significant. The range for this character was 37.09 (P118-2) to 60.54 (P-1312) over three years. The grand mean value remained at 43.84 over three years study. The mean values for early, medium and late maturity groups were 41.1, 41.9 and 52.4 respectively. Over the years the mean values were 45.5, 42.5 and 43.5 for first, second and third years respectively. Among the strains the highest grain number per spike was obtained in P-1312 (60.5) followed by P-1035 (58.0) and P-1142 (56.3) all from late maturity group. Among medium maturity group, strain P-108 (49.4) gave highest mean grain number per spike over the three years followed by P-766 (48.5) and the control HD-2428 (44.0). The highest mean values for this character in early maturity group, was found in strain KLM 3-5 (44.8) followed by the control HD-2285 (44.2). It is evident from above results that the strains P-1312 (60.5), P-1035 (58.0), P-1142 (56.3), P-108 (49.4), P-766 (48.5) and KLM 3-5 (44.8) gave higher mean grain

number per spike when compared to best controls HD-2285 (44.2) and HD-2428 (44.0). It shows that considerable improvement was achieved for this character when compared to controls.

4.1.9 Grain weight per spike

Highly significant differences were found among the genotypes of all three maturity groups for grain weight per spike. The group mean of strains for this character was high and non-significant than the controls. The mean values over three years ranged from 1.26 gms (NP-4) to 2.05 (P-1142), the grand mean over three years of study, for all maturity groups stood at 1.67. The mean grain weights per spike over years were 1.69, 1.72 and 1.59 gms, respectively in first, second and third years. The highest grain weight per spike was recorded in second year of study, followed by first and third years.

Among different maturity groups grain weight per spike in early, medium and late maturity groups were 1.74, 1.58 and 1.81 respectively giving best performance in the order of late, early and medium maturity groups. The highest grand mean value over years for the controls was found in cultivar HD-2428 (1.84) followed by HD-2285 (1.80) and C-306 (1.78) and among the strains the higher values were observed, viz., P-1142 (2.05), KLM-26 (1.99), P-1312 (1.94), P-1035 (1.89) and KLM3-5 (1.88).

4.1.10 1000-grain weight

The analysis of variance for 1000-grain weight showed highly significant values as in the case of grain number and grain weight in all maturity groups over all three years of

study. The group mean for strains (37.5) was slightly lower than the controls (38.9) and the grand mean value over three years for all genotypes including controls for all three maturity groups was 37.9 ranging from 32.23 (P-608) to 46.1 (KLM-26). Yearwise results revealed that highest grand mean 1000-grain weight was in second year (39.7 gms) followed by first (37.3) and third years (36.5). The highest mean value was observed in strain KLM-26 (45.5) and NP-850 (43.5) followed by P117-3 (43.3), P117-1 (41.0) and P38-15 (39.9) during first year. The highest mean 1000-grain weight was found to be in strain P118-2 (48.1) during second year, when compared to other two years of performance.

The grand group mean values over the years for early, medium and late maturity groups were 41.9, 37.0 and 34.4, respectively. It showed that early maturity group gave highest group mean value (41.9) followed by medium (37.0) and late (34.4) maturity groups. Among the controls, cultivar HD 2285 (41.4) gave highest grand mean value over years followed by cultivar HD 2428 (40.6).

4.1.11 Protein content

The analysis of variance for protein content was also found to be significant over years showing the existence of variation among the genotypes of all maturity groups. The genotype x year interactions were also found to be significant. The group mean value for strains (16.22%) was significantly higher than the controls (14.34%) showing the superiority of strains over controls, for this character. The grand mean value over years for strains and controls of all three maturity

groups together was 15.71%. It was ranged from 13.73 (HD 2160) to 18.04 (P117-3). Over the years the grand mean protein content was 14.9%, 15.8% and 16.5% during first, second and third years respectively, indicating the environmental effects on accumulation of protein content. The grand mean values for early, medium and late maturing genotypic groups were 16.5, 15.5 and 15.5 respectively. It is clearly evident that early maturing genotypes have higher protein content than medium and late maturity groups. Among the controls, the highest grand mean value over years was found in cultivar HD 2329 (14.8) followed by HD 2428 (14.2) and HD 2285 (14.0). All the strains were found to be superior to the best control for this character. Some of the following strains showed higher grand mean values for protein content than the controls viz., P117-3 (18.1), P117-1 (17.8), P118-2 (17.7), KLM-26 (17.6), Pusa 5-3 (17.3), P-766 (16.9), P38-15 (16.5) and P-102 (16.3). However, the strains P117-3 (19.3) and P118-2 (19.1) gave highest mean protein content during third year of experimentation.

4.1.12 Protein yield per square metre

Highly significant differences were revealed by analysis of variance for protein yield per square metre among the genotypes of all three maturity groups over three years of study. The group mean value of strains (66.70 gm/m^2) was higher than the controls (63.13). Eventhough this was non-significant, the difference was of higher order. The grand mean value for all maturity groups of strains and controls together was found to be 65.69 gm/m^2 and its range from 52.17 (P-1142) to 75.24 (P-766). The mean values of protein yield

over years were 64.7, 61.1 and 71.6, for first, second and third years respectively. The highest mean values of 95.4 was observed in P-108 during third year, 79.7 in P-932 during the second year and 76.6 in P-577 during the first year. These values for early, medium and late maturity groups were 64.9, 68.8 and 65.7 respectively. Among the controls, cultivar HD-2428 (75.1) yielded highest protein per square metre followed by HD-2329 (69.1) and HD-2285 (60.6). The strain P-766 (75.2) gave higher grand mean protein yield than the best control HD-2428 (75.1). However, the strain P-925 (83.7) and Pusa 5-3 (82.2) gave exceedingly higher mean values during third year than the best control HD-2329 (80.1).

4.1.13 Protein per grain

The analysis of variance for protein per grain showed existence of highly significant differences among the genotypes of all three maturity groups over three years. The group mean value for the strains (6.08) is higher than the controls (6.04). It showed the superiority of the strains over controls for this character. The grand mean value of all three maturity groups and controls together was 6.07 mg in all three years of study. The grand mean value ranged from 4.86 (P-1312) to 7.97 (NP-850). The mean values for the years were 5.57, 6.39 and 6.24 respectively for first, second and third years. The highest mean value for per grain protein during first year was observed in KLM-26 (7.66), during second year in P118-2 (8.68) followed by NP-850 (8.26), P117-3 (8.11), KLM-26 (7.87), P117-1 (7.83) and Pusa 5-3 (7.26) and during third year in NP-850 (8.76) followed

by KLM-26 (8.27), P117-3 (7.59) and P118-2 (7.47). Among the early, medium and late maturity groups the grand mean values were 6.92, 5.91 and 5.29 respectively. It was found to be evident that per grain protein values for early maturity group was higher (6.92) than medium (5.91) and late maturity groups (5.29).

Among the early maturity group, the strain KLM-26 (7.93), gave highest grand mean value followed by P118-2 (7.68) and P117-3 (7.44). The highest grand mean value over three years for controls was observed in cultivar HD-2285 (5.82) followed by HD-2428 (5.79) and HD-2329 (5.65). Most of the strains showed higher grand mean values for per grain protein when compared to the best control HD-2329 (5.65).

4.2 Correlation Studies

Genotypic and phenotypic correlations between all the thirteen pairs of characters were computed for early, medium and late maturity groups separately and pooled for strains and controls together over three years. These correlation values for all maturity groups pooled over three years were presented in Table 6 and the correlation values for early, medium and late maturity groups separately, pooled over three years were presented in Tables 7, 8 and 9 respectively.

It was clearly observed that the genotypic correlations were greater in magnitude than the phenotypic correlations in almost all strains and controls but were alike in significance.

At genotypic level tiller number per square metre in early maturity group showed significant positive correlations with spike length, grain number per spike and grain weight per spike. In medium maturity group, significant positive values were found only with harvest index, in late group correlations with plant height, protein content, protein yield and protein per grain were significant and positive.

In pooled analysis of all maturity groups, tiller number per unit area showed highly significant positive correlations with biomass, grain yield, harvest index and protein yield. At the same time, significant negative values were found with plant height, days to flower, spike length, grain number per spike, grain weight per spike, 1000-grain weight, protein content and protein per grain.

Table 6: Genotypic and phenotypic correlation coefficients among thirteen quantitative characters in eighteen strains and seven controls of all three maturity groups pooled over three years of study

Characters	Tiller number/ m ²	Plant height (cm)	Days to flower	Dry wt. of tillers (kg/m ²)	Grain yield (kg/m ²)	Harvest index (%)	Spike length (cm)	Grain number/ spike	Grain weight/ spike (gm)	1000-grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein per grain (mg)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1.	-	** -0.6804	-0.0764	* 0.3497	** 0.7029	** 0.6038	-0.2584	* -0.4227	* -0.3406	-0.0008	-0.3507	0.2977	-0.3358
2.	-0.2653	-	0.2289	* 0.3485	** -0.6189	** -0.7954	-0.3607	* -0.0398	-0.0335	0.0670	0.0210	0.3602	0.2900
3.	-0.0414	0.2176	-	* 0.4887	* 0.0436	-0.1245	-0.0622	* 0.5997	0.0787	-0.7062	-0.4718	-0.2588	-0.6645
4.	0.3261	0.1797	0.2315	-	* 0.3698	-0.0414	0.0080	-0.0222	0.1355	0.0394	-0.4004	0.1118	-0.2037
5.	* 0.4517	* -0.4543	0.0349	* 0.3980	-	** 0.9224	0.3230	-0.1429	-0.2628	-0.2526	-0.1658	0.7405	-0.4994
6.	0.2221	* -0.5543	-0.0947	-0.2913	** 0.7263	-	0.3280	-0.1134	-0.3286	-0.3207	-0.1135	0.6777	-0.5099
7.	0.0036	-0.2291	-0.0442	0.0129	0.1768	0.1399	-	* 0.5018	** 0.7171	0.1675	-0.1232	0.0707	-0.0808
8.	-0.0782	-0.0125	* 0.5158	0.0151	-0.0714	-0.0735	0.4407	-	** 0.6906	* -0.4716	-0.3261	* -0.5876	* -0.5836
9.	-0.0133	-0.0112	0.0590	0.0567	-0.1249	-0.1673	0.4726	* 0.6782	-	0.3102	-0.2434	-0.6750	0.0309
10.	0.0108	0.0315	** -0.6371	0.0237	-0.1870	-0.2163	0.0685	* -0.3656	0.3393	-	0.2307	-0.0621	** 0.8831
11.	-0.1387	0.0217	* -0.4278	-0.1372	-0.1057	-0.0837	-0.0828	* -0.2773	-0.1867	0.1679	-	* 0.4701	* 0.5516
12.	0.2663	-0.2106	-0.1752	0.3118	** 0.7660	* 0.5066	0.0201	* -0.3462	-0.3389	-0.0704	* 0.4367	-	-0.0185
13.	-0.1415	0.2401	** -0.6151	-0.0589	* -0.3721	* -0.3642	-0.0666	* -0.4825	0.0919	0.8500	** 0.5367	* 0.0572	-

Genotypic correlations above the diagonal, phenotypic correlations below the diagonal.

*, **: Significant at 5% and 1% level respectively.

Table 7: Genotypic and phenotypic correlation coefficients among thirteen quantitative characters in six strains and one control of early maturity group pooled over three years of study

Characters	Tiller Number/ m ²	Plant height	Days to flower	Dry wt. of tillers/ (kg/m ²)	Grain yield (kg/m ²)	Harvest index (%)	Spike length (cm)	Grain number/ spike	Grain weight/ spike (gm)	1000-grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein per grain (mg)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1.	-	** -0.7967	** -0.3272	** 0.7061	** 0.9639	0.1526	** 0.6142	** 0.7176	** 0.7483	* -0.3423	** -0.6860	-0.2613	** -0.7195
2.	0.0847	-	** 0.6639	* 0.4004	-0.0381	-0.5549	** 0.6844	** -0.6487	* 0.5893	** 0.7538	0.2889	0.0076	** 0.7015
3.	-0.2028	* 0.3947	-	** 0.6537	* 0.5669	-0.5670	** 0.6054	** 0.7531	** 0.6491	** 0.7363	-0.1867	-0.00	0.1989
4.	0.4849	0.2409	0.3506	-	0.8061	0.6748	0.1506	0.3832	0.8154	0.7267	-0.0372	0.70	-0.6881
5.	0.4841	0.0353	0.1157	0.4669	-	0.9111	0.7395	0.5400	0.7913	0.2245	-0.6956	0.3269	-0.7333
6.	0.1450	-0.2074	-0.2348	-0.2537	0.6815	-	0.2038	0.9490	0.9167	-0.6331	-0.7140	0.4534	-0.4241
7.	0.4678	0.1903	0.2892	0.3974	0.3172	-0.0440	-	0.4356	0.6458	0.5776	-0.7024	-0.0102	-0.3741
8.	0.6784	-0.2191	0.3093	0.1874	0.3942	0.2058	0.4093	-	0.4543	-0.6601	-0.7938	-0.4575	-0.6304
9.	0.4556	0.0372	0.5364	0.2294	0.2876	0.0133	0.4382	0.7204	-	0.4011	-0.6149	0.0065	-0.6722
10.	-0.0648	0.3945	0.3805	0.2429	0.0827	-0.1985	0.0729	-0.1693	0.5279	-	0.2755	0.0071	0.6666
11.	-0.4431	0.1640	-0.1877	-0.4187	-0.6780	-0.4080	-0.2780	-0.7077	-0.4160	0.1733	-	0.0069	0.9048
12.	-0.1512	0.1981	-0.1211	-0.1022	0.2198	0.2534	-0.1697	-0.3457	-0.1794	0.1630	0.3566	-	0.0080
13.	-0.3445	0.3050	0.0823	-0.1604	-0.4371	-0.4007	-0.1659	-0.5875	-0.0111	0.6634	0.8153	0.3804	-

*, ** : Significant at 5% and 1% level respectively.

Genotypic correlations are above the diagonal;

Phenotypic correlations are below the diagonal.

Table 8: Genotypic and phenotypic correlation coefficients among thirteen quantitative characters in eight strains and five controls of medium maturity group pooled over three years of study

Characters	Tiller number/ m ²	Plant height	Days to flower	Dry wt. of tillers (kg/m ²)	Grain yield (kg/m ²)	Harvest index (%)	Spike length (cm)	Grain number/ spike	Grain weight/ spike (gm)	1000-grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein per grain (mg)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1.	-	**	*		*	*							*
2.	-0.4248	-	0.1382	0.2296	-0.7105	-0.8081	-0.4211	-0.5253	-0.2613	0.1880	0.2572	-0.3286	0.6335
3.	0.2381	0.1316	-	0.6576	0.2197	-0.0362	-0.2965	0.3008	-0.0596	-0.3187	0.1592	0.5054	-0.2338
4.	0.3041	0.1083	0.3099	-	0.2150	-0.2080	0.1429	0.3726	**	0.2870	0.4322	0.4173	0.1940
5.	0.4223	-0.5832	0.1972	0.3372	-	0.9237	0.5641	0.8189	0.5032	-0.3123	0.0899	0.8110	-0.7604
6.	0.1796	-0.6208	-0.0282	-0.4025	0.7042	-	0.5139	0.7174	0.2687	-0.3979	-0.1556	0.6432	-0.8341
7.	-0.1065	-0.2864	-0.2114	-0.0278	0.3120	0.2834	-	0.9995	0.8855	0.1855	-0.0576	0.7162	-0.0806
8.	0.0269	-0.3152	0.2129	0.1604	0.5385	0.3980	0.7614	-	0.4529	-0.2001	0.2393	0.7387	-0.3729
9.	0.0263	-0.1425	-0.0357	0.3012	0.3410	0.1484	0.5676	0.5181	-	0.7889	-0.2595	0.6075	0.4252
10.	-0.0480	0.1447	-0.2852	0.1344	-0.2448	-0.2846	0.0881	-0.1450	0.5863	-	-0.3454	-0.5404	0.8466
11.	-0.0599	0.2019	0.1260	0.2237	0.0905	-0.1200	-0.0963	0.1147	-0.1790	-0.2974	-	0.8872	-0.0004
12.	0.2407	-0.1657	0.2901	0.4885	0.7653	0.3498	0.2114	0.5486	0.2643	-0.3117	0.6671	-	-0.7912
13.	-0.2678	0.5544	-0.2162	0.1104	-0.6169	-0.6341	-0.0926	-0.2852	0.3161	0.8189	0.0957	-0.3220	

*, **: Significant at 5% and 1% level respectively.

Genotypic correlations are above the diagonal

Phenotypic correlations are below the diagonal

Table 9: Genotypic and phenotypic correlation coefficients among thirteen quantitative characters in four strains and one control of late maturity group pooled over three years of study

Characters	Tiller number/ m ²	Plant height (cm)	Days to flower	Dry wt. of tillers (kg/m ²)	Grain yield (kg/m ²)	Harvest index (%)	Spike length (cm)	Grain number/ spike	Grain weight/ spike (gm)	1000-grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein per grain (mg)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1.	-	0.5113	-0.6170	0.5422	0.9611	0.7703	-0.6692	-0.7137	0.8365	0.4599	0.3717	0.7411	0.7619
2.	0.1759	-	-0.5930	0.6527	-0.3539	-0.7071	-0.5171	-0.4063	-0.1970	0.8220	-0.8063	-0.1879	
3.	-0.5781	-0.5159	-	-0.6577	-0.6577	-0.2746	0.7140	0.7023	0.9302	-0.7790	-0.1453	-0.7814	0.6
4.	0.2919	0.4231	-0.5331	-	0.5198	-0.0246	-0.9975	-0.9941	-0.6818	0.6398	-0.2632	0.6019	0.7924
5.	0.4652	-0.1841	-0.4063	0.5220	-	0.8514	-0.8037	-0.6785	-0.9714	-0.4506	0.9838	0.9889	-0.2727
6.	0.3334	-0.4346	-0.1815	-0.1809	0.7050	-	-0.3986	-0.2859	-0.8075	-0.6781	0.8008	0.8316	-0.9440
7.	-0.0422	-0.2821	0.5164	-0.2261	-0.2180	-0.1264	-	0.6515	0.9904	-0.5449	-0.2728	-0.9357	-0.8408
8.	-0.3978	-0.3208	0.9098	-0.4568	-0.4170	-0.2234	0.6554	-	0.9224	-0.4836	-0.2276	-0.7963	-0.8013
9.	-0.1989	-0.1268	0.6706	-0.2901	-0.5258	-0.4697	0.6294	0.8552	-	-0.1161	-0.8489	-0.7118	-0.5711
10.	0.3375	0.5890	-0.5554	0.4850	-0.2421	-0.6098	-0.1003	-0.2991	0.2002	-	-0.7564	-0.4010	0.9397
11.	0.0498	-0.3823	-0.0384	-0.1442	0.5880	0.8162	0.0287	-0.1333	-0.4118	0.6512	-	0.8615	-0.7575
12.	0.5068	-0.0525	-0.5050	0.5297	0.9673	0.7076	-0.3060	-0.5247	-0.6499	-0.2547	0.6621	-	-0.1808
13.	0.4936	0.8258	-0.8047	0.6197	-0.1206	-0.4909	-0.2976	-0.5677	-0.1619	0.8757	-0.4345	-0.0191	-

Genotypic correlations above the diagonal, phenotypic correlations below the diagonal.

*, **: Significant at 5% and 1% level respectively.

At phenotypic level, tiller number showed highly significant positive correlations in early maturity group with spike length, grain weight per spike and grain number per spike whereas in medium maturity group, tiller number had positive significant correlations only with grain yield and negative with plant height. In late maturity group, significant positive values were found with protein yield and protein per grain and negative values with spike length, grain weight per spike and grain number per spike. The results of pooled analysis of three maturity groups over three years, showed that tiller number had significant positive correlation with grain yield only.

It was observed that both at genotypic and phenotypic levels plant height showed significant and positive associations with biomass and 1000-grain weight in early maturing group. However, days to flower, spike length, grain weight per spike and protein per grain were found significant and positively correlated with plant height at genotypic level only. On the other hand, plant height showed significant and negative correlations with harvest index and grain number per spike at genotypic levels. At both genotypic and phenotypic levels, plant height showed significant and positive correlations with protein per grain and significant negative correlations with grain yield and harvest index in medium maturity group. But spike length had significant negative value at genotypic level only. In late maturity group at both levels biomass, 1000-grain weight and protein per grain showed significant and positive correlations with plant height.

Significant negative correlations were observed at genotypic level with grain yield, harvest index, spike length, grain number per spike, grain weight per spike, protein content and protein yield, but at phenotypic level significant and negative correlations were observed only for biomass and harvest index with plant height.

In the pooled analysis of all three maturity groups together over three years, only biomass had significant positive correlations with plant height at genotypic level but none of the characters showed significant correlations with plant height at phenotypic level, on the contrary showed significant and negative value for grain yield and harvest index. Negative correlations were also significant for grain yield, harvest index, spike length and protein yield with plant height at genotypic level.

Days to flower showed significant positive correlations with biomass, grain weight per spike and 1000-grain weight at both genotypic and phenotypic levels in early maturity groups, but correlations with grain yield, spike length and grain number per spike were significant and positive only at genotypic level. None of the values were significant negatively with days to flower except harvest index at genotypic level. In medium maturity group, only biomass and protein yield were found to be significant and positively correlated with days to flower. No significant phenotypic correlations were noticed in this group. In late maturity group, days to flower showed highly significant and positive correlations with spike length, grain number per spike and grain weight per spike and high significant negative

correlations with biomass, grain yield, 1000-grain weight, protein yield and protein per grain at both genotypic and phenotypic level.

In pooled analysis, days to flower had shown significant positive correlation at both levels with grain number per spike and significant negative correlations with 1000-grain weight, protein per cent and protein per grain. Biomass was positively correlated with days to flower at both levels, but significant at genotypic level only.

Biomass in early maturity group showed significant positive correlations with all characters studied at genotypic level except protein content which showed significant negative correlation. At phenotypic level, it showed significant positive correlation with grain yield and significant negative correlation with protein per cent.

For biomass, genotypic correlations were observed to be highly significant and positive with grain weight per spike, protein per cent and protein yield in medium maturity group. Whereas, phenotypic correlations were significant and positive with harvest index and negative with protein yield. In the late maturity group, biomass had shown significant positive correlations with grain yield, 1000-grain weight, protein yield and protein per grain at both genotypic and phenotypic levels. It showed significant negative correlations with spike length, grain number and grain weight per spike at genotypic level and only with grain number per spike at phenotypic level.

In pooled analysis, biomass showed significant positive correlation with grain yield only and significant negative correlation only with protein per cent, at both genotypic and phenotypic levels.

At both genotypic and phenotypic levels, grain yield showed significant positive correlations with harvest index and grain number per spike and negative correlations with protein per cent and protein per grain in early maturity group. Whereas in medium maturity group, positive and significant correlations were observed with harvest index, protein yield, grain number and grain weight per spike, and only negative values with protein per grain at both genotypic and phenotypic levels. Grain yield in late maturity group exhibited highly significant positive correlations with harvest index, protein per cent and protein yield and significant negative correlations with protein per grain, grain number and grain weight per spike at both genotypic and phenotypic levels, whereas it showed significant negative correlations with spike length and 1000-grain weight at genotypic level only. Grain yield in pooled analysis exhibited highly significant positive correlations with harvest index and protein yield and significant negative association with per grain protein at both genotypic and phenotypic levels.

Harvest index in early maturity group had shown significant positive relationships with protein yield, grain number and grain weight per spike at genotypic level and no significant positive correlations were found at phenotypic level. But significant negative association was noticed

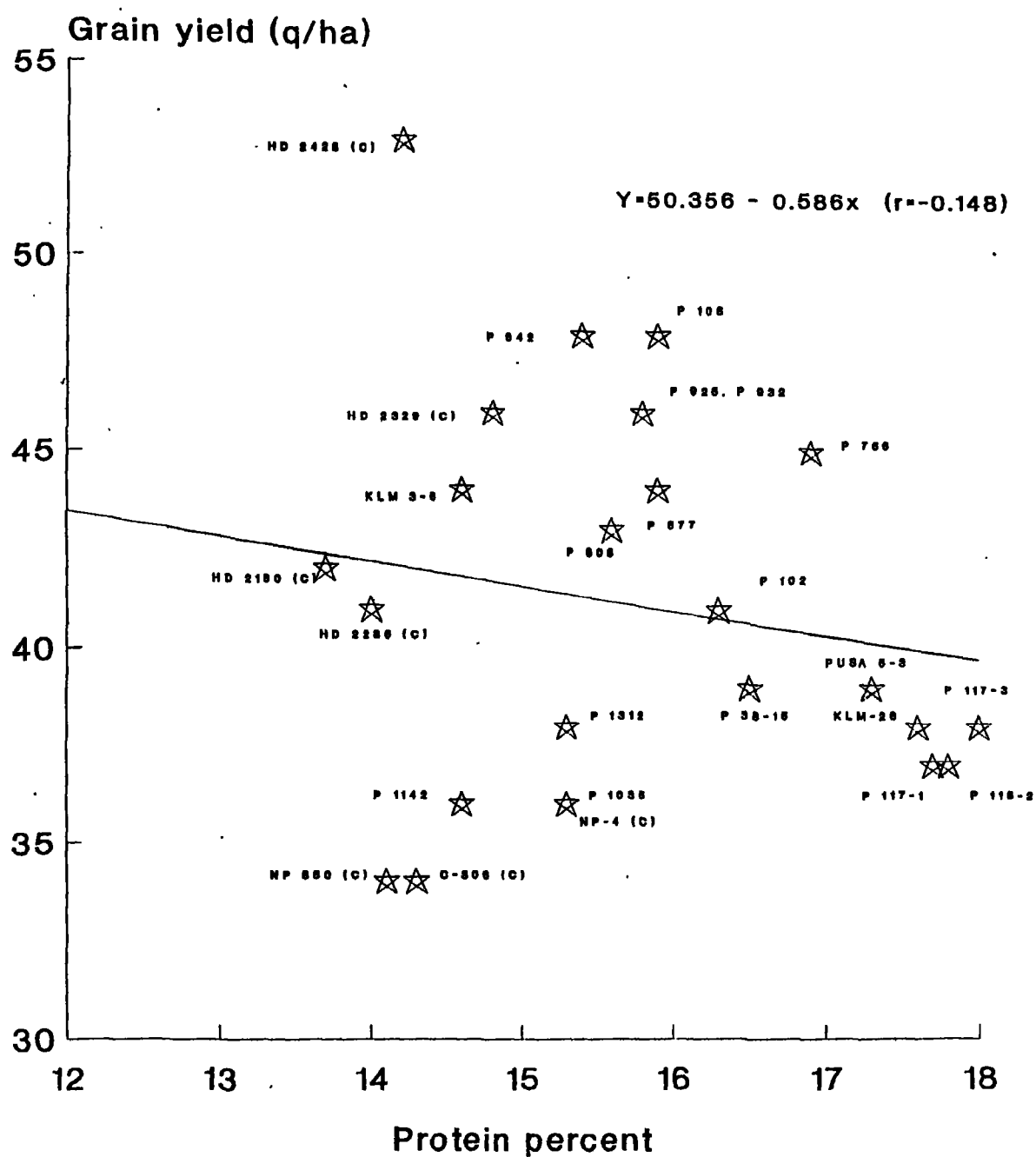


Fig. 1. RELATIONSHIP BETWEEN GRAIN YIELD AND PROTEIN PERCENT

between harvest index and protein per cent and protein per grain both at phenotypic and genotypic levels, and 1000-grain weight at genotypic level. In medium maturity group, harvest index exhibited noteworthy positive association with grain number per spike and protein yield and significant negative association with protein per grain at both genotypic and phenotypic level. An impressive positive correlation was also noticed between harvest index and spike length and grain weight per spike and a negative correlation between harvest index and 1000-grain weight at genotypic level.

Harvest index in late maturity group showed highly significant positive correlations with protein per cent and protein yield and also same degree of negative association with 1000-grain weight, grain weight per spike, and protein per grain at both genotypic and phenotypic levels. Harvest index in pooled analysis showed highly significant positive correlation with protein yield and highly significant negative association with protein per grain at both genotypic and phenotypic levels.

Spike length at both genotypic and phenotypic levels showed impressive positive correlations with grain number and grain weight per spike in all three maturity groups separately and also in pooled analysis.

In addition, spike length also showed significant positive correlations with 1000-grain weight in early maturity group and protein yield in medium maturity group. Spike length in early maturity group was negatively correlated with protein per cent and protein per grain at both genotypic and

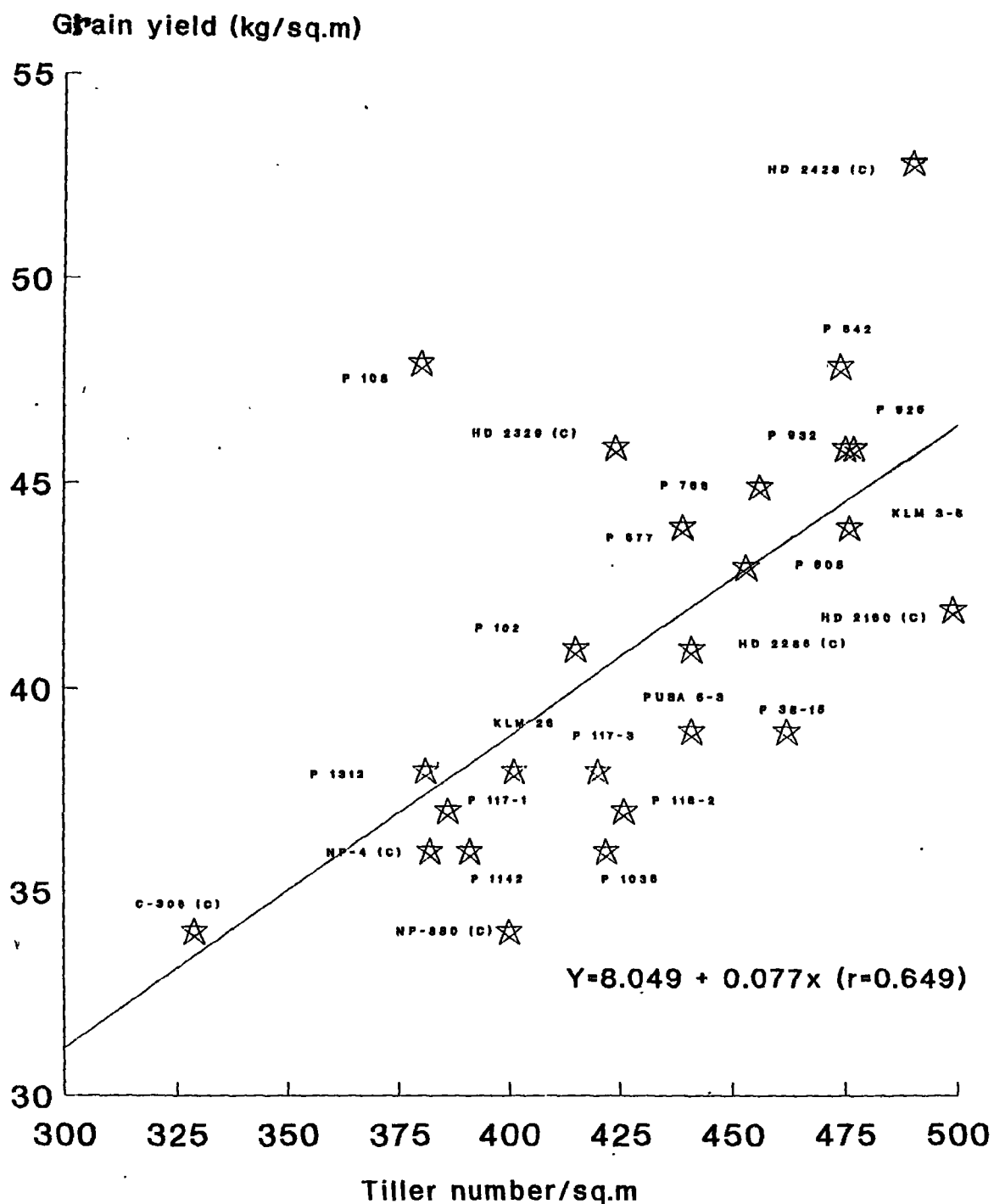


Fig. 2. RELATIONSHIP BETWEEN GRAIN YIELD AND
TILLER NUMBER

phenotypic levels, but these were significant at genotypic level only. Whereas in late maturity group, it showed negative correlations with 1000-grain weight, protein yield and protein per grain at both genotypic and phenotypic levels, but significant at former level only.

Grain number per spike had shown significant positive correlation only with grain weight per spike in all three maturity groups and also in pooled analysis at both genotypic and phenotypic levels. At the same time, it showed negative correlations with 1000-grain weight, protein per cent, protein yield and protein per grain in all maturity groups together and separately at both genotypic and phenotypic levels, but significant only in early and late maturity groups and in pooled analysis.

Grain weight per spike was significantly positively correlated with 1000-grain weight in early and medium maturity groups at both genotypic and phenotypic levels. It is negatively correlated with protein per cent, protein yield and protein per grain in all maturity groups pooled and separately at both genotypic and phenotypic levels, except in medium maturity group, in which it was positively correlated. In pooled analysis, no negative values were observed in all the maturity groups except with protein yield, at genotypic level.

1000-grain weight had shown significant positive correlation with protein per grain in all three maturity groups and also in pooled analysis at genotypic and phenotypic levels and it was negatively correlated with protein per cent and protein yield in all maturity groups separately and

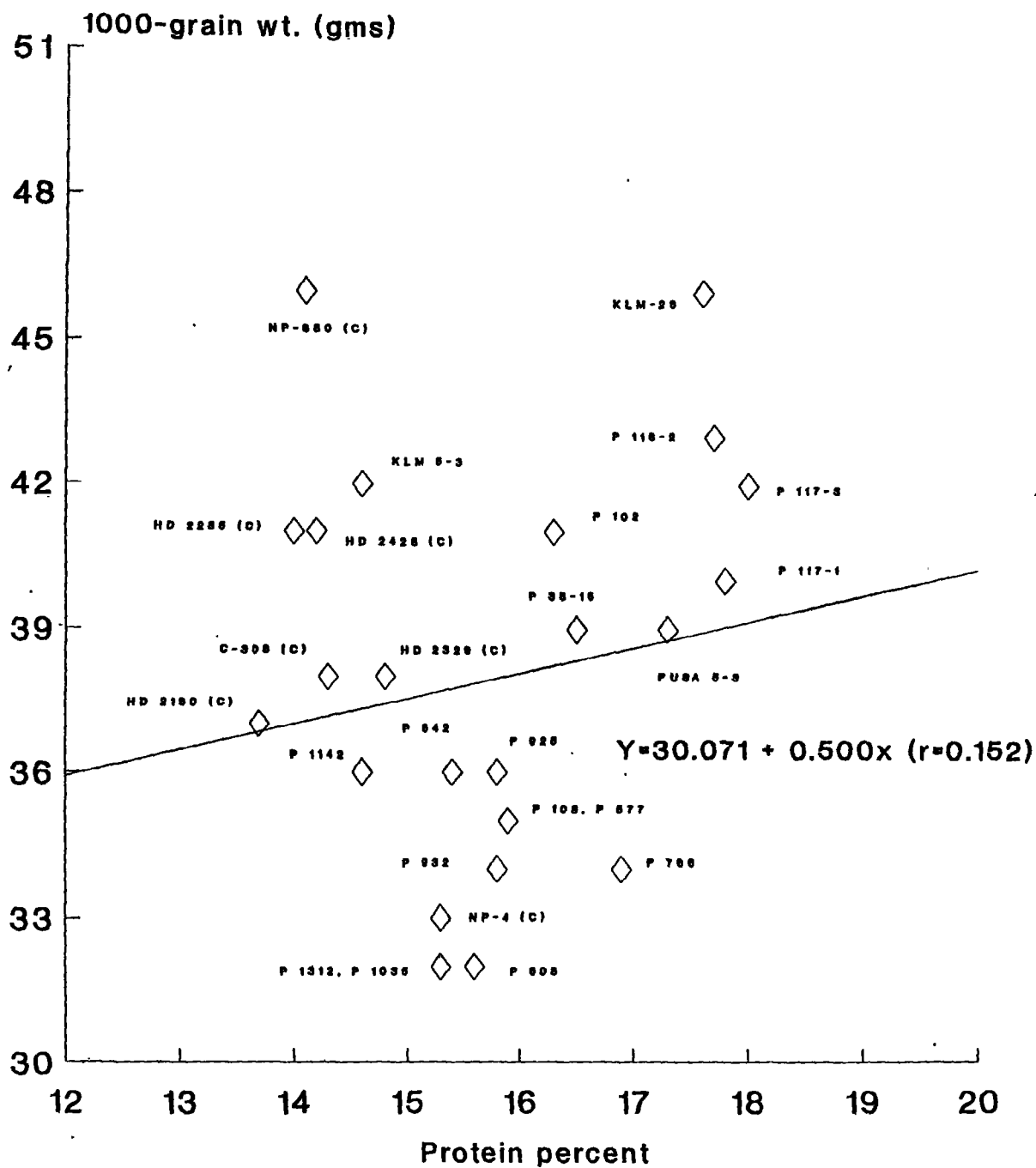


fig. 3. RELATIONSHIP BETWEEN PROTEIN PERCENT AND
1000-GRAIN WEIGHT

jointly at both genotypic and phenotypic levels, but correlation values were significant in medium and late maturity groups at genotypic level only.

Protein per cent showed highly significant positive correlation with protein yield per square metre in all three maturity groups and also in pooled analysis at both genotypic and phenotypic levels. Significant positive correlations were also found between protein per cent and protein per grain in early maturity group and pooled analysis at both genotypic and phenotypic levels, but in medium and late maturity groups protein per cent was negatively correlated with protein per grain at both genotypic and phenotypic levels, but significant only in late maturity group.

Protein yield was positively correlated with protein per grain in early maturity group and negatively correlated in other two maturity groups at both genotypic and phenotypic level, but significant only in early maturity group at phenotypic level and in medium maturity group at genotypic level. Protein yield had highly significant positive correlations with protein per cent, harvest index and grain yield per square metre and significant negative correlations with grain number and grain weight per spike both at genotypic and phenotypic levels when all three maturity groups were clubbed.

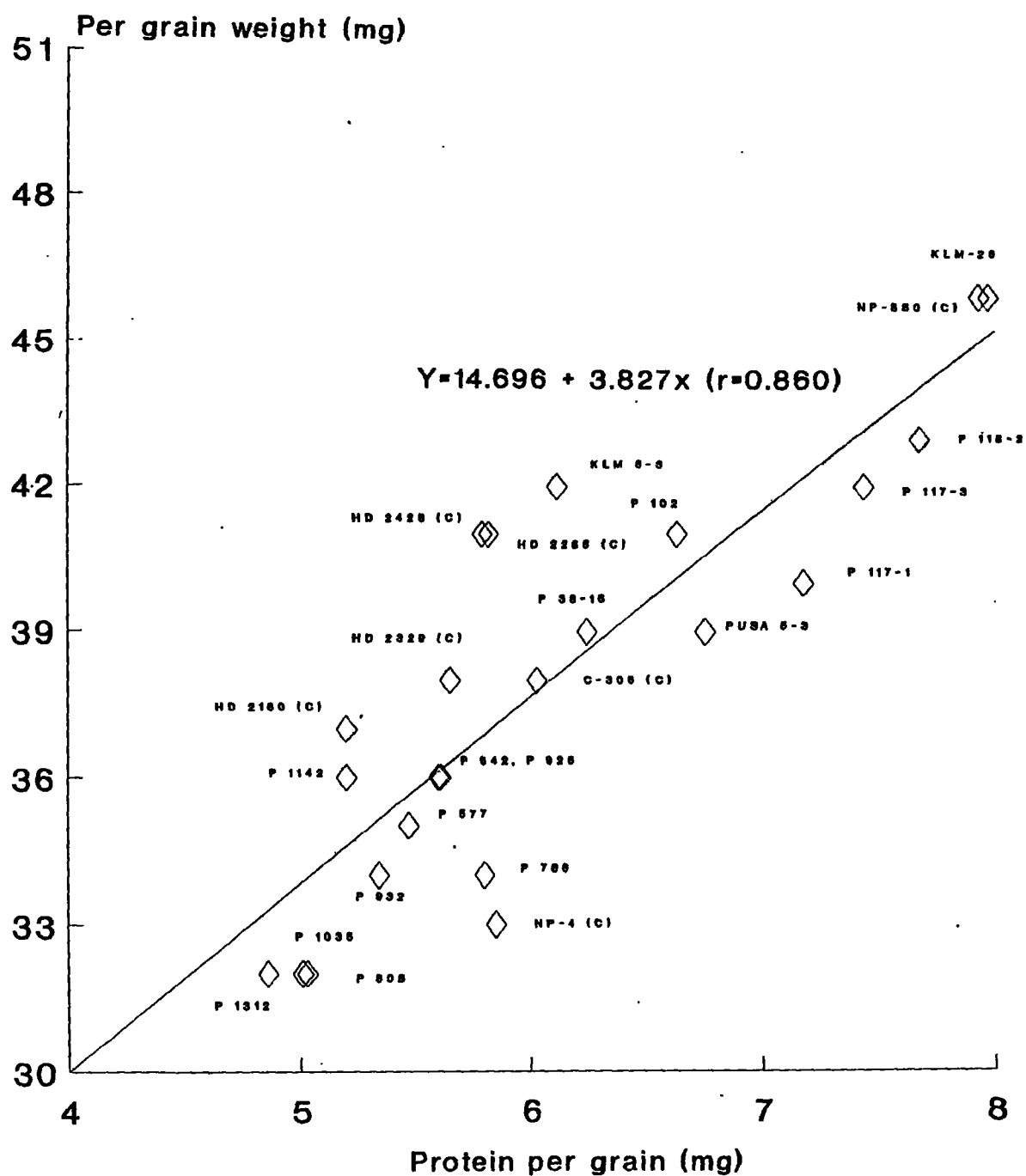


Fig. 4. RELATIONSHIP BETWEEN PROTEIN PER GRAIN AND PER GRAIN WEIGHT

4.3 Path Analysis

Linear correlation between yield and various structural and growth components can represent a confusing picture because of interrelationships among the components themselves. For this reason, path coefficient analysis (or standard partial regression) provide a much more realistic picture of the factors involved.

This analysis was undertaken for early, medium and late maturity group separately and a pooled analysis was conducted for three groups over three years of study. The characters under study were yield and yield components viz., tiller number per square metre, plant height, days to flower, biomass, harvest index, spike length, grain number per spike, grain weight per spike, 1000-grain weight, protein per cent, protein yield and protein per grain. Grain yield per square metre was considered as the 'effect' and the other twelve yield attributes mentioned above as 'causes'. The genotypic path analysis was computed in the strains and controls together in all maturity groups separately and also in three groups combined together (Tables 10 to 13).

Tiller number per square metre did not contribute directly towards yield, but showed high positive indirect effects via biomass, harvest index, spike length, and grain weight per spike in pooled analysis of all three maturity groups. Tiller number per square metre also did not contribute directly towards yield in early and late maturity groups as in pooled analysis, but showed high positive indirect effects via biomass, harvest index, grain weight per spike, 1000-grain

Table 10: Path coefficient analysis showing direct (diagonal) and indirect effects of different characters on grain yield in eighteen strains and seven controls of all three maturity groups pooled over three years of study

Characters	Tiller No./ Sq.m	Plant height (cm)	Days to flower	Dry wt. of tillers (kg/sq.m)	Harvest index (%)	Spike length (cm)	Grain number /spike	Grain weight /spike (gm)	1000-grain weight (gm)	Protein content (%)	Protein yield (g/sq.m.)	Protein per grain (mg)	rg value with yield
	(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	
1.	-0.1857	-0.2388	-0.0324	0.2213	1.5493	0.1488	-0.5319	0.2599	-0.0009	-0.1542	-0.1891	-0.1433	0.7029
2.	0.1264	0.3510	0.0972	0.2205	-0.0411	0.2076	-0.0501	0.0256	0.0824	0.0092	0.2285	0.1237	-0.6189
3.	0.0142	0.0803	0.4247	0.3092	-0.3195	0.0358	0.7548	-0.0601	-0.8690	-0.2075	0.1643	-0.2836	0.0436
4.	-0.0649	0.1223	0.2075	0.6328	-0.1063	-0.0046	-0.0280	-0.1034	0.0484	-0.1761	0.0710	-0.0869	0.3698
5.	-0.1121	-0.2792	-0.0529	-0.0262	2.5661	-0.1888	-0.1428	0.2508	-0.3946	-0.0499	-0.4304	-0.2176	0.9224
7.	0.0480	-0.1266	-0.0264	0.0051	0.8416	-0.5756	0.6315	-0.5472	0.2061	-0.0542	-0.0449	-0.0345	0.3230
8.	-0.0785	-0.0140	0.2547	-0.0141	-0.2911	-0.2888	1.2586	-0.5269	-0.5803	-0.1434	0.3732	-0.2490	-0.1429
9.	0.0632	-0.0118	0.0334	0.0857	-0.8433	-0.4128	0.8691	-0.7630	0.3818	-0.1070	0.4286	0.0132	-0.2628
10.	0.0001	0.0235	-0.2999	0.0249	-0.8229	-0.0964	-0.5935	-0.2367	1.2306	0.1015	0.0394	0.3768	-0.2526
11.	0.0651	0.0074	-0.2004	-0.2534	-0.2913	-0.0709	-0.4104	0.1857	0.2838	0.4398	-0.2985	0.2354	-0.1658
12.	-0.0553	-0.1264	-0.1099	0.0707	1.7391	-0.0407	-0.7396	0.5151	-0.0764	0.2068	-0.6350	-0.0079	0.7405
13.	0.0624	0.1018	-0.2822	-0.1289	-1.3085	0.0465	-0.7345	-0.0236	1.0866	0.2426	0.0117	0.4267	-0.4993

Residual effect (Rx) = -0.0393. The underlined values denote direct effects.

rg = Genotypic correlation coefficient values.

Table 11: Path coefficient analysis showing direct (diagonal) and indirect effects of different characters on grain yield in six strains and one control of early maturity group pooled over three years of study

Chara- cters	Tiller No./ Sq.m.	Plant height (cm)	Days to flower	Dry wt. of tillers (kg/sq.m.)	Harvest index (%)	Spike length (cm)	Grain number /spike	Grain weight /spike (gm)	1000- grain weight (gm)	Protein content (%)	Protein yield (g/sq.m.)	Protein per grain (mg)	rg value with yield
	(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	
1.	-0.0303	-0.0252	-0.0547	1.2024	0.1014	-0.0615	-0.1036	0.0136	0.0366	0.5546	0.2618	-0.6695	0.9639
2.	0.0241	0.0316	0.1109	0.1145	-0.3689	-0.0718	0.0295	0.0037	-0.1341	-0.0950	0.2730	0.3174	-0.0381
3.	0.0099	0.0210	0.1671	0.7586	-0.3769	-0.0610	-0.0343	0.0098	-0.0788	-0.6140	0.3077	0.0900	0.5669
4.	-0.1274	0.0127	0.4434	0.2859	1.3791	-0.1911	-0.0629	0.0241	-0.2382	0.9992	0.2933	-0.7186	0.8061
6.	-0.0046	-0.0175	-0.0947	0.5931	0.6647	-0.0124	-0.0887	0.0058	0.1105	0.3994	-0.1963	-0.6444	0.9111
7.	-0.0307	0.0375	0.1680	0.9007	0.1354	-0.0605	-0.0198	0.0091	-0.0618	0.2311	0.3614	-0.1693	0.7395
8.	-0.0690	-0.0205	0.1258	0.3954	1.2955	-0.0264	-0.0455	0.0029	0.0706	0.4585	0.1714	-0.6473	0.6400
9.	-0.0651	0.0186	0.2589	1.0907	0.6093	-0.0877	-0.0207	0.0063	-0.0429	0.3339	0.3404	-0.3041	0.7973
10.	0.0104	0.0396	0.1230	0.6366	-0.6867	-0.0350	0.0300	0.0025	-0.1070	-0.0908	0.1151	0.3016	0.2245
11.	0.0511	0.0091	-0.0312	-0.8683	-0.8069	0.0426	0.0634	0.0064	-0.0295	-0.3290	-0.2025	0.4094	-0.4956
12.	0.5372	-0.3299	-0.8466	1.7640	-0.3181	-0.4045	1.0459	-0.1081	2.0763	0.6093	0.1792	-0.4789	0.7010
13.	0.0448	0.0220	0.0332	-0.4540	-0.9466	0.0277	0.0651	-0.0042	-0.0713	-0.2977	-0.0525	0.4525	-0.7333

Residual effect (Rx)= -0.0136. The underlined values denote direct effects.

rg= Genotypic correlation coefficient values.

Table 12: Path coefficient analysis showing direct (diagonal) and indirect effects of different characters on grain yield in eight strains and five controls of medium maturity group pooled over three years of study

Characters	Tiller No./m ²	Plant height (cm)	Days to flower	Dry wt. of tillers (kg/m ²)	Harvest index (%)	Spike length (cm)	Grain number/spike	Grain weight/spike (gm)	1000-grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein per grain (mg)	rg value with yield
	(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	
1.	0.0619	-0.1816	-0.0151	-0.0233	-0.1751	0.0122	-0.0014	-0.0189	-0.0999	0.0027	0.1063	0.9053	0.5732
2.	-0.0485	0.2315	-0.0042	-0.0483	0.2648	0.0312	-0.0402	0.0389	0.3246	-0.0045	-0.2358	-0.2199	-0.7105
3.	0.0308	0.0320	-0.0303	-0.1384	0.0119	0.0220	0.0230	0.0089	-0.5503	-0.0028	0.3627	0.4502	0.2197
4.	0.0068	0.0532	-0.0199	-0.2104	0.0681	-0.0106	0.0285	-0.1146	0.4956	-0.0076	0.2995	-0.3737	0.2150
6.	0.0330	-0.1871	0.0011	0.0438	-0.3277	-0.0381	0.0549	-0.0400	-0.6871	0.0027	0.4616	1.6064	0.7042
7.	-0.0102	0.0975	0.0090	-0.0301	-0.1684	-0.0740	0.0765	-0.1317	0.3203	0.0010	0.5140	0.1552	0.3120
8.	-0.0011	-0.1216	-0.0091	-0.0784	-0.2351	-0.0740	0.0765	-0.0674	-0.3456	-0.0042	0.9607	0.7181	0.5385
9.	0.0079	-0.0605	0.0018	-0.1622	-0.0881	-0.0656	0.0347	-0.1487	1.3622	0.0045	0.4360	-0.8189	0.3410
10.	-0.0036	0.0435	0.0097	-0.0604	0.1304	-0.0137	-0.0153	-0.1173	1.7267	0.0060	-0.3878	-1.6305	-0.2448
11.	-0.0096	0.0595	-0.0048	-0.0909	0.0510	0.0043	0.0183	0.0386	-0.5964	-0.0175	0.6367	0.0008	0.0905
12.	0.0092	-0.0761	-0.0153	-0.0878	-0.2108	-0.0530	0.1025	-0.0903	-0.9330	-0.0155	0.7176	1.5236	0.7653
13.	-0.0291	0.1466	0.0071	-0.0408	0.2733	0.0060	-0.0285	-0.0632	1.4619	0.0000	-0.5678	-1.9258	-0.6169

Residual effect (Rx) = -0.0111. The underlined values denote direct effects.

rg= Genotypic correlation coefficient values.

Table 13: Path coefficient analysis showing direct (diagonal) and indirect effects of different characters on grain yield in four strains and one control of late maturity group pooled over three years of study

Chara- cters	Tiller No./ m ²	Plant height (cm)	Days to flower	Dry.wt of tillers (kg/m ²)	Harvest index (%)	Spike length (cm)	Grain number/ spike	Grain weight/ spike (gm)	1000- grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein per grain (mg)	rg value with yield
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	
1.	-0.0453	0.0810	-0.2438	0.0230	0.0442	-0.0122	0.9318	-0.6554	0.1299	0.0004	1.3411	-0.6338	0.9611
2.	-0.0231	0.1584	-0.0717	0.0277	-0.0406	-0.0040	0.2209	-0.0703	0.2323	-0.0009	-0.2031	-0.5794	-0.3539
3.	0.0913	-0.0939	0.1209	-0.0449	-0.0158	0.0086	-0.5993	0.3320	-0.2201	-0.0002	-0.8444	0.6151	-0.6507
4.	-0.0245	0.1034	-0.1278	0.0424	-0.0014	-0.0077	0.5405	-0.2433	0.2938	-0.0003	0.6504	-0.7056	0.5198
6.	-0.0349	-0.1120	-0.0332	-0.0010	0.0574	-0.0031	0.1555	-0.2882	-0.3046	0.0015	0.8986	0.5154	0.7050
7.	0.0710	-0.0819	0.1346	-0.0423	-0.0229	-0.0078	-0.5717	0.3534	-0.1540	-0.0003	-1.0111	0.5136	-0.2180
8.	0.0776	-0.0643	0.1332	-0.0422	-0.0164	0.0082	-0.5437	0.3292	-0.1366	-0.0003	-0.8606	0.4375	-0.4170
9.	0.0831	-0.0312	0.1124	-0.0289	-0.0464	0.0077	-0.5016	0.3569	-0.0328	-0.0010	-1.2015	0.3118	-0.5258
10.	-0.0228	0.1302	-0.0942	0.0441	-0.0619	-0.0042	0.2630	-0.0415	0.2826	-0.0014	-0.4334	-0.5130	-0.2421
11.	-0.0168	-0.1277	-0.0176	-0.0112	0.0747	-0.0021	0.1237	-0.3029	-0.3350	0.0011	0.9310	0.6865	0.5880
12.	-0.0562	-0.0298	-0.0944	0.0255	0.0477	-0.0073	0.4330	-0.3968	-0.1133	0.0010	1.0806	0.0987	0.9673
13.	-0.0525	0.1681	-0.1362	0.0548	-0.0542	-0.0073	0.4357	-0.2038	0.2655	-0.0014	-0.1954	-0.5460	-0.1206

Residual effect (Rx)= 0.0000. The underlined values denote direct effects.

rg= Genotypic correlation coefficients.

weight, protein per cent and protein yield in early maturity group. It had also shown negative indirect effects via plant height, days to flower, spike length, grain number per spike followed by protein per grain in this group.

In medium maturity group, tiller number contributed directly to the grain yield, and its indirect positive effects were via spike length, protein content, protein yield and protein per grain. In late maturity group also tiller number did not contribute to the grain yield directly, but contributed through high positive indirect effects via plant height, biomass, harvest index, grain number per spike, 1000-grain weight and protein yield. It had also showed negative indirect effects via days to flower, spike length, grain weight per spike and protein per grain.

The direct effect of plant height was positive in all three maturity groups via., early, medium and late, and in pooled analysls. In early group, its indirect effects were positive via all the yield attributes except harvest index, spike length, 1000-grain weight and protein per cent which showed negative effects. In medium maturity group indirect effects of plant height towards yield were positive via harvest index, spike length, grain weight per spike followed by 1000-grain weight, but negative via rest of the yield components.

Though plant height showed positive direct effect in late maturity group, its indirect effects were negative via most of the yield attributes except biomass, grain number per spike

and 1000-grain weight, where these were positive. In pooled analysis, indirect effects of plant height towards grain yield were mostly positive except via harvest index and grain number with negative effects.

Days to flower showed high positive (0.425) direct effect in pooled analysis. It was positive in early and late maturity groups but showed relatively low negative value (0.030) in medium maturity group. The indirect effects of days to flower seems to be positive in all the maturity groups and pooled analysis via tiller number per square metre, plant height and biomass. Its contribution via biomass in early group is relatively high (0.7586). In all three maturity groups and pooled group, its indirect effects towards grain yield were negative via protein per cent and 1000-grain weight.

The indirect contribution towards grain yield of days to flower via protein per grain was positive and very high (0.6151) in late group, followed by medium maturity group (0.4502) and early maturity group (0.090), but in pooled analysis it seems to be negative with relatively low magnitude.

The direct effect of biomass on yield was positive and quite high (0.6328) in pooled analysis i.e. all three maturity groups combined together over three years. It was positive with low magnitude in early and late maturity group but negative with low magnitude in medium maturity group.

The indirect effects of biomass showed positive and high in magnitude via days to flower (0.4434), harvest index (1.3791) followed by protein per cent (0.9992) and negative

and high in magnitude via protein per grain (-0.7186), followed by 1000-grain weight (-0.2382) in early maturity group. In medium maturity group, the indirect effects of biomass were positive via tiller number per unit area, plant height, harvest index, protein yield, grain number and grain weight per spike, but negative via days to flower, spike length, 1000-grain weight, protein per cent and protein per grain. In late maturity group, indirect effect of biomass was positive and high in magnitude via protein yield (0.6504) followed by grain number per spike (0.5405), but negative with high magnitude via protein per grain (0.7056). In pooled analysis, biomass showed positive indirect effect towards yield via plant height, days to flower, 1000-grain weight and protein yield, but negative indirect effects were via tiller number, harvest index, spike length, grain number, grain weight per spike, protein per cent and protein per grain.

Harvest index had shown a very high positive direct effect on yield in pooled analysis of all three maturity groups (2.5661), followed by early maturity group (0.6647) and late maturity group. It showed negative direct effect of moderately low in magnitude (-0.3277) in medium maturity group.

The indirect effects of harvest index towards yield were positive and moderately high in magnitude via biomass (0.5931) and were positive with relatively low in magnitude via grain weight per spike, 1000-grain weight and protein per cent, but negative via rest of the yield attributes in early maturity group. In medium maturity group its indirect effects were

positive and very high in magnitude via protein per grain (1.6064) followed by protein yield (0.4616). It was positive, except via plant height, spike length, grain weight, grain weight and 1000-grain weight. Harvest index had positive indirect effects with high magnitude via protein yield (0.8986) and protein per grain (0.5154) in late maturity group. In pooled analysis its positive indirect effect was only via grain weight per spike and its indirect effects via all other yield components were negative.

The direct effect of spike length was negative in all three maturity groups and also in pooled analysis, but its value was moderately high in magnitude (-0.5756) in pooled analysis. However, very high positive indirect effects were also observed via harvest index (1.2955) and protein per cent (1.4585) in early maturity group, via protein yield (0.5140) in medium maturity group, via protein yield (0.5140) in medium maturity group, via protein per grain (0.5136) in late maturity group and via harvest index (0.8416) and grain number (0.6316) in pooled analysis. It also showed high negative indirect effects through protein yield (-1.0111) in late group, protein per grain (-0.6473) in early group and grain weight per spike (-0.5472) in combined analysis.

Grain number per spike exhibited very high positive direct effect (1.2586) in pooled analysis, moderately high negative value (-0.5437) in late maturity group and low positive value in medium maturity group. The direct effect of grain number on yield in early maturity group was negative with relatively low magnitude. But the indirect effects were

very high and positive via harvest index (1.2955) and protein per cent (0.4585) in early maturity group. It was via protein yield (0.9607) and protein per grain (0.7181) in medium maturity group and via protein per grain (0.4373) in late maturity group. In pooled analysis its positive indirect effects were only through days to flower and protein per cent (0.3782).

Grain number per spike displayed high negative indirect effects also via protein yield (-0.8606) in late maturity group and via 1000-grain weight (-0.5803) and grain weight per spike (0.5269) in pooled analysis. It was also noticed that the indirect effects of grain number per spike were positive via most of the yield attributes in early maturity group and negative via most of the yield components in medium, late and pooled analysis.

The direct effect of grain weight per spike showed moderately high negative effect in pooled analysis, and relatively low negative effect in medium maturity group. In early and late maturity groups, it showed positive direct effect towards yield, the magnitude being low and moderate respectively. Its positive indirect contribution through biomass (1.0907) and harvest index in early maturity group, through 1000-grain weight (1.3622) and protein yield (0.4360) in medium maturity group and through grain number per spike (0.8691) and protein yield (0.4286) in pooled analysis were high. It had high magnitude of negative indirect effects via protein yield (-1.2015) and grain number per spike (-0.5016) in late maturity group, via protein per grain (-0.8189) in

medium maturity group and harvest index (-0.8413), spike length (-0.4128) in pooled analysis.

The indirect effects of 1000-grain weight towards grain yield were positive and high via biomass (0.6366) in early maturity group. Its indirect effects were mostly negative and high through different yield attributes, for example, via protein per grain (-1.6305) and protein yield (-0.3878) in medium maturity group, harvest index (-0.6867), in early maturity group, harvest index (-0.6867), in early maturity group, protein per grain (-0.5130) and protein yield (-0.4334) in late maturity group and harvest index (-0.5229) and grain number (-0.5935) in pooled analysis. The negative indirect effects were more via many characters in all groups except early maturity group.

The direct effect of protein per cent in pooled analysis was moderately high and positive (0.4398) and in late maturity group it was of low order. But it was moderately high and negative in early group followed by medium maturity group. The indirect effects were very high and positive via protein yield in late maturity group (0.9310) and medium maturity group (0.6367) and via protein per grain in late maturity group (0.6865) and early maturity group (0.4094). The negative indirect effects were high via biomass (-0.8683) and harvest index (-0.8069) in early maturity group, via 1000-grain weight (-0.5964) in medium maturity group and via grain number per spike (-0.4104) in pooled analysis.

Protein yield per square metre witnessed very high positive direct effect in late maturity group (1.0806)

followed by a high positive value in medium maturity group (0.7176) and positive and low in early maturity group. The pooled analysis showed a moderately high negative direct effect (-0.6350).

The indirect effects of protein yield were very high and positive via 1000-grain weight (2.0763), biomass (1.7604), grain number (1.0459), protein per cent (0.6093) and tiller number (0.5373) in early maturity group. In medium maturity group, the highest positive indirect effect was observed via protein per grain (1.5236). It was highest via harvest index (1.7391) followed by grain weight (0.5151) in pooled analysis.

The decreasing order of magnitude of negative indirect effects of protein yield were as follows. Through grain number (0.7396) in pooled analysis and protein per grain (-0.4789) and spike length (-0.4045) in early maturity group.

Protein per grain showed very high negative direct effect on grain yield in medium maturity group (-1.9258) followed by moderately high in magnitude (-0.5460) in late maturity group. But it was positive and moderately high in early maturity group (0.4525) and pooled analysis (0.4267).

Indirect effects of protein per grain were very high and positive via 1000-grain weight in medium maturity group (1.4619) followed by pooled analysis (1.0866) and moderately high via grain number (0.4357) in late group. The negative indirect effects were high through harvest index in pooled analysis (-1.3085) followed by early maturity group (-0.9466), grain number in pooled analysis (-0.7345) and protein yield in medium maturity group (-0.5678).

4.4 Studies on Heritability and Genetic Advance

Considering the preponderance of G x E interaction in the material studied, it was decided to study the variability parameters, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2_b), genetic advance (GA as % of mean), grand mean and range based on pooled analysis of strains and controls together in early, medium and late maturity groups and combined analysis of all maturity groups put together.

Tables 14 to 17 gives the above mentioned six different parameters for each thirteen characters in early medium and late maturity groups and in pooled analysis of above three groups. In general, it was observed that GCV is generally lower than the PCV for all characters, in all three maturity groups and pooled analysis. Regarding the phenotypic coefficient of variation (PCV), it ranged from 7.21 (days to flowering) to 15.90 (grain number per spike) followed by grain weight per spike (14.59), tiller number per square metre (13.35) and plant height (13.21) in pooled analysis. In early maturity group, PCV ranged from 1.62 (days to flower) to 13.81 (protein per grain) and for other traits were in the order of tiller number (12.59). Harvest index (11.02), grain weight per spike (10.66) and grain yield (10.18). In medium maturity group by PCV ranged from 1.42 (days to flower) to 16.55 (plant height). In medium maturity group, comparatively much phenotypic variation exists in tiller number per square metre (13.74) and for protein per grain (13.85) in this group. The PCV in late maturity group ranged from 1.13 (days to flower)

Table 14: Phenotypic coefficient of variation (PCV), Genotypic coefficient of variation (GCV), heritability (h^2_b), genetic advance (GA), grand mean and range of thirteen characters in eighteen strains and seven controls of all three maturity groups pooled over three years of study

Characters	PCV	GCV	h^2_b	GA as % of mean	Grand mean	Range
1. Tiller number/m ²	13.35	5.91	0.1959	5.39	433.58	380.3-499.4
2. Plant height (cm)	13.21	12.46	0.8896	24.20	98.26	63.8-126.7
3. Days to flower	7.21	7.19	0.9952	14.77	84.56	74.3- 94.0
4. Dry weight of tillers(kg/m ²)	8.90	4.13	0.2159	3.68	1.36	1.23- 1.48
5. Grain yield (kg/m ²)	12.62	10.28	0.6629	17.07	0.41	0.34- 0.53
6. Harvest index (%)	12.72	9.38	0.5445	14.26	31.27	24.8 -37.9
7. Spike length (cm)	7.88	5.15	0.4264	6.93	9.96	9.16-11.34
8. Grain number/spike	15.99	13.75	0.7404	24.38	43.84	37.07-60.54
9. Grain weight/spike (gm)	14.59	10.44	0.5118	15.57	1.67	1.26- 2.05
10. 1000-grain weight (gm)	11.56	10.43	0.8131	19.36	37.86	32.23-46.10
11. Protein content(%)	8.45	7.64	0.8187	14.26	15.71	13.73-18.04
12. Protein yield (g/m ²)	11.31	7.76	0.4713	10.98	65.69	52.17-75.24
13. Protein per grain (mg)	16.11	14.89	0.8545	28.34	6.07	4.86- 7.96

Table 15: Phenotypic coefficient of variation (PCV), Genotypic coefficient of variation (GCV), Heritability (h^2_b), Genetic Advance (GA), Grand mean and Range of thirteen characters in six strains and one control of early maturity group pooled over three years of study.

Characters	PCV	GCV	h^2_b	GA as % mean	Gran mean	Range
1. Tiller number/m ²	12.59	3.26	0.0670	1.74	430.16	385.8 - 475.8
2. Plant height (cm)	5.36	3.08	0.3303	3.64	96.33	90.0 - 102.7
3. Days to flower	1.62	1.38	0.7212	2.40	76.19	74.3 - 76.7
4. Dry weight of tillers (kg/m ²)	8.72	1.31	0.0226	0.76	1.32	1.23- 1.39
5. Grain yield (kg/m ²)	10.18	4.58	0.2019	5.13	0.39	0.37- 0.44
6. Harvest index (%)	11.02	3.19	0.0837	1.90	30.56	27.8 - 33.5
7. Spike length (cm)	6.13	2.62	0.1823	2.30	10.02	9.58- 10.59
8. Grain number/spike	8.94	4.49	0.2516	4.65	41.31	37.1 - 44.5
9. Grain weight/spike (gm)	10.66	4.28	0.1617	3.45	1.74	1.60- 1.90
10. 1000-grain weight (gm)	7.26	5.06	0.4853	7.26	41.89	38.50- 46.1
11. Protein content (%)	10.11	9.58	0.8977	18.72	16.61	14.00- 18.0
12. Protein yield (g/m ²)	8.81	0.05	0.0000	0.00	64.86	60.60- 68.3
13. Protein per grain (mg)	13.81	11.68	0.7152	20.38	6.92	5.82- 7.93

Table 16: Phenotypic coefficient of variation (PCV), Genotypic coefficient of variation (GCV), Heritability (h^2_b), Genetic advance (GA), Grand mean and Range of thirteen characters in eight strains and five controls of medium maturity group pooled over three years of study

Characters	PCV	GCV	h^2_b	GA as % mean	Grand mean	Range
1. Tiller number/m ²	13.74	7.55	0.3020	8.55	440.9	380.3 - 499.4
2. Plant height (cm)	16.55	15.87	0.9193	31.34	96.6	63.8 - 126.7
3. Days to flower	1.42	1.37	0.9396	2.74	85.8	83.3 - 88.4
4. Dry weight of tillers(kg/m ²)	8.24	3.85	0.2188	3.65	1.37	1.25- 1.48
5. Grain yield (kg/m ²)	11.60	10.14	0.7641	18.60	0.43	0.34- 0.53
6. Harvest index (%)	12.56	10.06	0.6411	16.60	32.60	24.8 - 37.9
7. Spike length (cm)	9.14	6.78	0.5515	10.36	9.94	9.16- 11.3
8. Grain number/spike	9.93	7.16	0.5202	10.62	41.9	37.9 - 49.1
9. Grain weight/spike (gm)	12.86	8.63	0.4503	12.03	1.58	1.26- 1.84
10. 1000-grain weight (gm)	10.62	9.50	0.8015	17.54	37.0	32.2 - 45.6
11. Protein content (%)	7.13	6.05	0.7187	10.52	15.5	13.7 - 17.3
12. Protein yield (g/m ²)	8.35	4.76	0.3248	5.58	68.8	59.4 - 75.2
13. Protein per grain (mg)	13.85	12.83	0.8578	24.53	5.91	5.20- 7.97

Table 17: Phenotypic coefficient of variation (PCV), Genotypic coefficient of variation (GCV), Heritability (h^2_b), Genetic advance (GA), Grand mean and Range of thirteen characters in four strains and one control of late maturity group pooled over three years of study

Characters	PCV	GCV	h^2_b	GA as % mean	Grand mean	Range
1. Tiller number/m ²	15.12	4.74	0.0982	3.06	419.3	380.8 - 475.2
2. Plant height (cm)	10.55	10.01	0.8999	19.55	105.4	98.3 - 124.4
3. Days to flower	1.13	1.08	0.9159	2.14	93.0	91.6 - 94.0
4. Dry weight of tillers (kg/m ²)	9.86	5.92	0.3604	7.19	1.39	1.24 - 1.48
5. Grain yield (kg/m ²)	14.92	11.20	0.5641	18.42	0.38	0.35 - 0.46
6. Harvest index (%)	13.23	9.56	0.5227	14.24	28.8	25.0 - 33.0
7. Spike length (cm)	7.73	3.75	0.2353	3.72	9.95	9.40 - 10.32
8. Grain number/spike	18.94	16.12	0.7245	28.26	52.4	40.4 - 60.5
9. Grain weight/spike (gm)	17.62	13.16	0.5577	20.44	1.81	1.81 - 2.05
10. 1000-grain weight (gm)	8.10	6.28	0.6018	10.06	34.41	32.18 - 38.14
11. Protein content (%)	4.87	3.01	0.3818	3.85	15.07	14.29 - 15.84
12. Protein yield (g/m ²)	16.83	12.86	0.5838	20.24	58.89	52.17 - 73.55
13. Protein per grain (mg)	8.59	6.82	0.6308	11.15	5.29	4.86 - 6.03

to 18.94 (grain number per spike). More phenotypic variation was observed for grain weight per spike (17.62) followed by protein yield per square metre (16.83) and tillers per square metre (15.12).

Genotypic coefficient of variation (GCV) ranged from 1.31 (biomass) to 11.68 (protein per grain) in early maturity group; from 1.37 (days to flower) to 12.83 (protein per grain), in medium maturity group, from 1.08 (days to flower) to 16.12 (grain number per spike) in late group and from 4.13 (dry weight of tillers) to 14.89 (protein per grain) in pooled analysis. It is evident that more genetic variation exists among the genotypes for protein per grain, followed by grain number and grain weight per spike, in all the maturity groups in general.

Heritability values ranged from 0.1959 (tiller number/m²) to 0.9952 (days to flower), in pooled analysis. Some of other characters showing high degree of heritability in pooled analysis were plant height (0.8896), protein per grain (0.8545) protein per cent (0.8187), 1000-grain weight (0.8131). Grain number per spike (0.7404) followed by grain yield (0.6629). Protein per cent had highest heritability values (0.8977) followed by days to flower (0.7212) and protein per grain (0.7152) in early maturity group and in medium maturity group, high degree of heritability were in the order of days to flowering (0.9396), plant height (0.9193), protein per grain (0.8578), 1000-grain weight (0.8015) and grain yield (0.7641). In case of late maturity group, the values for days to flower (0.9159) and plant height (0.8999) seems to be highly heritable by grain number per spike (0.7245), protein

per grain (0.6308) and 1000-grain weight (0.6018).

Genetic advance percentage in early maturity group ranged from 0.76 (dry matter production) to 20.38 (protein per grain). Genetic advance percentage in medium maturity group ranged from 2.74 (days to flower) to 31.34 (plant height), the range in late maturity group was from 2.14 (days to flower) to 28.26 (grain number per spike). Highest values of GA % in pooled analysis was observed for protein per grain (28.34) followed by grain number per spike (24.38) and plant height (24.20).

In early maturity group, protein per grain showed highest GA followed by protein per cent (18.72%). In medium maturity group protein per grain (24.53) also showed high genetic advance value, followed by grain yield (18.60), 1000-grain weight (17.54) and harvest index (16.60).

Grain number showed high genetic advance value (28.26) followed by grain weight per spike (20.44), protein yield (20.24) and grain yield (18.42) in late maturity group.

4.5 Nitrogen Accumulation Studies

The analysis of variance for protein content as a whole revealed significant differences among the genotypes of all maturity groups when considered separately and also in pooled analysis. The data on protein accumulation at different stages of grain development, after flowering was analysed statistically and the results were presented in (ANOVA) Tables 18, 19, 20 and 21 for early, medium, late and pooled analysis respectively. The treatment means of six stages of protein accumulation in strains and controls of all three maturity groups over three years of study is presented in Table 22. A brief summary showing significant results depicting various stages of protein accumulation of strains in comparison with controls in each group was presented in Table 23.

4.5.1 Stage I (15 Days after flowering)

Analysis of variance for protein accumulation at stage-I i.e. fifteen days after flowering showed existence of significant genotypic differences among the genotypes of early, medium and late maturity groups separately and also in pooled analysis. The treatment mean sum of squares and Y x T interaction sum of squares were highly significant, in all the maturity groups.

The group means of early and late maturity strains were slightly differing than the controls but were not significant. But in medium maturity group (12.46), the group mean for strains was very high and significant, showing the superiority of strains over controls. In pooled analysis, the group mean

Table 18: Summary of analysis of variance in respect of six stages of protein accumulation in eighteen strains and seven controls of all three maturity groups pooled over three years of study

Source of Variation	degrees of freedom	SUM OF SQUARES					
		Stage I (15 DAF)	Stage II (22 DAF)	Stage III (29 DAF)	Stage IV (36 DAF)	Stage V (43 DAF)	Stage VI (Harvest) ^a
Year	2	0.021	0.0049	0.0117	0.0117	0.0137	0.002
Replication	2	0.167	0.3877	0.0371	0.1016	0.7520	0.410
Y x R	4	0.447	0.3252	0.0020	0.2178	0.9629	0.588
Treatment	24	5.848**	5.2375**	3.8307**	5.5243**	8.6234**	10.011**
Y x T	48	0.188	0.2196	0.2136	0.2392	0.1928	0.255
Error	144	0.276	0.3287	0.3000	0.3014	0.3237	0.522

DAF : Days after flowering

** : Significant at 1% level

a : protein in harvest sample

Table 19: Summary of analysis of variance in respect of six stages of protein accumulation in six strains and one control of early maturity group pooled over three years of study

Source of variation	degrees of freedom	SUM OF SQUARES					
		Stage I (15 DAF)	Stage II (22 DAF)	Stage III (29 DAF)	Stage IV (36 DAF)	Stage V (43 DAF)	Stage VI (Harvest ^a)
Year	2	5.551**	3.963**	11.147**	18.893**	7.134**	3.962**
Replication	2	0.270	0.615	0.338	0.249	0.321	1.907
Y x R	4	0.269	0.057	0.218	0.052	0.148	0.255
Treatment	6	5.544**	8.328**	8.062**	11.351**	10.567**	13.106**
Y x T	12	0.750**	0.506**	0.533**	0.747**	1.876**	2.267**
Error	36	0.086	0.142	0.129	0.129	0.127	0.370 °

DAF = Days after flowering

** = Significant at 1% level

a = protein in harvest sample

Table 20: Summary of analysis of variance in respect of six stages of protein accumulation in eight strains and five controls of medium maturity group pooled over three years of study

Source of Variation	degrees of freedom	SUM OF SQUARES					
		Stage I (15 DAF)	Stage II (22 DAF)	Stage III (29 DAF)	Stage IV (36 DAF)	Stage V (43 DAF)	Stage VI (Harvest) ^a
Year	2	6.121**	5.088**	11.063**	25.164**	20.564**	29.241**
Replication	2	0.580	0.798	0.836	0.066	0.869	0.615
Y x R	4	0.048	0.017	0.271	0.157	0.330	0.463
Treatment	12	6.869**	3.933**	5.984**	7.874**	9.093**	9.986**
Y x T	24	0.651**	0.661**	1.949**	1.776**	2.942**	2.317**
Error	72	0.097	0.149	0.236	0.151	0.160	0.232

DAF = Days after flowering

** = Significant at 1% level

a = protein in harvest sample

Table 21: Summary of analysis of variance in respect of six stages of protein accumulation in four strains and one control of late maturity group pooled over three years of study

Source of Variation	degrees of freedom	SUM OF SQUARES					
		Stage I (15 DAF)	Stage II (22 DAF)	Stage III (29 DAF)	Stage IV (36 DAF)	Stage V (43 DAF)	Stage VI (Harvest) ^a
Year	2	0.733	0.561	5.978**	6.854**	7.408**	4.578**
Replication	2	1.874	0.120	0.034	0.358	0.640	0.258
Y x R	4	1.294	0.100	0.396	0.187	0.496	0.879
Treatment	4	1.302	0.892**	0.885**	3.423**	3.783**	0.859**
Y x T	8	1.750	1.595**	0.644*	1.521**	2.258**	1.670**
Error	24	0.968	0.118	0.203	0.208	0.363	0.310

DAF = Days after flowering

*,** = Significant at 5% and 1% level respectively

a = protein in harvest sample

of strain was less than the controls but not significant.

4.5.2 Stage II (22 Days after flowering)

Analysis of variance revealed highly significant differences among the genotypes of all three maturity groups separately and combinedly. Y x T interactions were significant in all three maturity groups, but not in pooled analysis. The protein accumulation ranged from 9.82 per cent (KLM 3-5) to 12.80 (P118-2) in early maturity group. The pooled analysis value for early group was 12.54 at this stage and the group mean of strains (11.46) was significantly higher than the control (10.51).

In medium maturity group, the protein accumulation value at this stage ranged from 9.80 (HD 2160) to 12.32 (Pusa 5-3). Most of the strains showed higher protein accumulation than controls of this stage. The group mean value for medium maturity group strains (11.05) was significantly higher than the controls (10.21). In late maturity group, protein accumulation values ranged from 10.58 (P-1312) to 11.31 (C-306). The overall group mean (10.66) is lower than that of early (11.32) and medium (10.73) groups. When compared to control the strains showed lower group mean value, in this late maturity group. In pooled analysis strains showed higher value but non-significant.

4.5.3 Stage III (29 Days after sowing)

Analysis of variance showed the existence of highly genotypic differences among the genotypes of all three maturity groups separately and together. The protein accumulation values at this stage was high in medium maturity group

Table 22: Treatment means of six stages of protein accumulation in strains and controls of three maturity groups over three years of study

Strains/ Cultivar	STAGES OF PROTEIN ACCUMULATION					
	I (15 DAF)	II (22 DAF)	III (29 DAF)	IV (36 DAF)	V (43 DAF)	VI (Harvest) ^a
Early maturity group						
1. P 38-15	12.47	11.62	12.93	14.59	15.96	15.99
2. P 117-1	12.49	11.17	12.34	14.30	15.57	16.31
3. P 117-3	12.67	11.43	13.98	15.19	16.66	16.86
4. P 118-2	13.36	12.80	13.64	15.28	16.42	16.63
5. KLM 3-5	11.03	9.82	11.17	12.43	13.70	14.22
6. KLM-26	13.39	11.90	13.46	14.88	16.20	16.86
7. HD 2285 (Control)	12.41	10.51	12.71	12.90	14.52	14.06
Group mean	12.54	11.32	12.89	14.22	15.57	15.85
Medium maturity group						
8. P 102	12.73	11.12	14.08	15.87	16.28	16.30
9. P 108	12.31	10.98	13.47	14.63	16.17	15.89
10. P 577	11.52	10.52	12.66	14.70	15.70	15.87
11. P 608	12.84	10.74	13.19	15.01	15.36	15.63
12. P 642	11.86	10.56	13.33	14.61	15.40	15.42

Contd..

Table 22 (Contd....)

Strains/ Cultivars	STAGES OF PROTEIN ACCUMULATION					
	I (15 DAF)	II (22 DAF)	III (29 DAF)	IV (36 DAF)	V (43 DAF)	VI (Harvest) ^a
13. P 766	12.53	11.31	14.09	15.58	16.52	16.77
14. P 925	11.92	10.81	13.80	14.93	15.48	15.90
15. Pusa 5-3	13.97	12.32	14.34	16.22	17.10	17.30
16. NP-4 (Control)	11.29	10.64	12.29	13.98	15.14	15.28
17. NP-880 (Control)	11.53	10.72	12.79	13.89	14.64	14.11
18. HD 2160 (Control)	10.69	9.80	12.07	13.11	13.59	13.73
19. HD 2329 (Control)	12.41	9.91	12.58	14.13	14.78	14.78
20. HD 2428 (Control)	11.09	10.00	11.87	13.30	13.91	14.18
Group Mean	12.05	10.73	13.12	14.61	15.39	15.47
Late maturity group						
21. P 932	12.11	10.62	13.28	14.97	15.90	15.74
22. P 1035	12.12	10.62	13.57	14.88	15.51	15.41
23. P 1142	12.28	10.61	13.24	14.08	14.44	14.63
24. P 1312	11.44	10.58	12.70	14.11	15.11	15.39
25. C 306 (Control)	12.44	11.31	13.17	13.49	14.43	14.42
Group mean	12.08	10.75	13.19	14.30	15.08	15.12
Grand mean	11.92	10.66	12.57	13.74	14.79	14.88

DAF= Days after flowering; a= protein in harvest sample.

(13.12) followed by early (12.89) and late (12.57) maturity groups. It was high in strains than controls of all three maturity groups but significant only in medium maturity group. In medium maturity group, the values ranged from 11.87 (HD 2428) to 14.34 (Pusa 5-3) and most of the strains showed high values of protein accumulation, for example, the strain P-766 (14.09), P-102 (14.08) and P-925 (13.80) etc.

4.5.4 Stage IV (36 Days after flowering)

Highly significant differences among the genotypes were revealed by analysis of variances in all three maturity groups separately and in pooled analysis, it is evident from the performance of different genotypes in each group. In early maturity group, the range of protein accumulation was from 12.43 (KLM 3-5) to 15.28 (P118-2) in medium maturity group it was from 13.11 (HD 2160) to 16.22 (Pusa 5-3) and in late maturity group from 13.49 (C-306) to 14.97 (P-932). The group means of early, medium and late maturity groups were 14.22, 14.61 and 14.30 respectively. It is evident that medium maturing genotypes gave higher values followed by late and early groups. The grand mean value at this stage was 13.74. The group mean value for early maturing strains (14.45) was significantly higher than the control HD 2285 (12.90). The group mean of medium maturing strains (15.19) was also significantly higher than the controls (13.68). In late maturity group also, strains showed high group mean value (14.51) than control C-306 (13.49) in this group.

Table 23: Brief summary showing significant differences between the protein accumulation stages of strains in comparison with controls

Protein accumulation stages	Maturity group	Group Mean		C.D. at 5%	G_1-G_2	Remarks
		Strains (G_1)	Controls (G_2)			
1. I (15 DAF)	Early	12.57	12.41	0.28	0.16	NS
	Medium	12.46	11.40	0.29	1.05	S
	Late	11.99	12.44	0.96	-0.45	NS
	Pooled	12.21	11.16	0.49	1.05	S
2. II (22 DAF)	Early	11.46	10.51	0.36	0.95	S
	Medium	11.05	10.21	0.36	0.83	S
	Late	10.61	11.31	0.33	-0.70	-S
	Pooled	10.80	10.29	0.53	0.51	NS
3. III (29 DAF)	Early	12.92	12.71	0.35	0.21	NS
	Medium	13.62	12.32	0.46	1.30	S
	Late	13.20	13.17	0.44	0.03	NS
	Pooled	12.67	12.32	0.51	0.35	NS
4. IV (36 DAF)	Early	14.45	12.90	0.25	1.55	S
	Medium	15.19	13.68	0.37	1.51	S
	Late	14.51	13.49	0.46	1.02	S
	Pooled	13.86	13.44	0.51	0.42	NS
5. V (43 DAF)	Early	15.75	14.52	0.34	1.23	S
	Medium	16.00	14.41	0.38	1.59	S
	Late	15.24	14.43	0.57	0.81	S
	Pooled	14.92	14.45	0.53	0.47	NS
6. VI(Harvest) ^a	Early	16.15	14.06	0.59	2.09	S
	Medium	16.14	14.42	0.45	1.72	S
	Late	15.29	14.42	0.54	0.87	S
	Pooled	14.26	14.21	0.67	0.04	NS

S= Significant; NS= Non-significant; a= protein in harvest sample

4.5.5 Stage V (43 Days after flowering)

Analysis of variance revealed that highly significant differences were existed among the genotypes of all three maturity groups in accumulating protein at this stage. The protein accumulation values ranged from 13.70 (KLM 3-5) to 16.66 (P117-3) in early, from 13.59 (HD 2160) to 17.10 (Pusa 5-3) in medium, and from 14.43 (C-306) to 15.90 (P-932) in late maturity group. The group mean values were 15.57, 15.39 and 14.79 respectively for early, medium and late maturity groups, except KLM 3-5 (13.7). In early maturity group, all the strains accumulated higher percentage of protein than the control HD 2285 (14.52). In medium maturity group, all the strains showed high percentage of protein than controls and in late group also all strains are superior than the cultivar C-306 in accumulating protein.

The group mean value for early maturity 8 strains (15.75) was significantly higher than the control (14.52) in medium maturity groups and the late maturity group also the group mean for strains was significantly higher than controls.

4.5.6 Stage VI (Harvest)

Analysis of variance for protein accumulation at this stage showed the existence of highly significant differences among the genotypes of all three maturity groups. The group mean values for early, medium and late maturity groups were, 15.85, 15.47 and 14.88 respectively. It was clearly understood that early maturity group showed high percentage of

accumulation than medium and late groups. In early maturity group, all six genotypes gave high percentages of protein accumulation than the control HD 2285 and the group mean value for strains (16.15) was significantly higher than the control (14.06). In medium maturity group also all the genotypes gave higher protein accumulation values than the controls individually and also in pooled analysis. The group mean value for strains (16.14) was significantly higher than the controls (14.40). In late maturity group also, all the genotypes viz., P-932 (15.74), P-1035 (15.41), P-1142 (14.63), and P-1312 (15.39) gave higher protein accumulation values than the control C-306 (14.42) in this group. The group mean value for strains (15.29) was significantly higher than the control (14.42), showing superiority of the strains over the control.

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5. DISCUSSION

Plant breeding research in recent years led to significant advances in the yields of food-grains like wheat (Borlaug, 1968; Chandler, 1972). A large part of this advance has been contributed by a few major genes such as 'Norin-10' dwarfing genes in bread wheat. The high yielding varieties of this crop had a significant impact on food production and perhaps for the first time, developing countries like India, are becoming increasingly conscious of the problem of malnutrition resulting from deficiency of protein in the vegetarian diet, in addition, to the more familiar problem of calories. The possibility of improving the quantity and quality of protein in cereal grains has received considerable attention in this context. Our studies have made it clear that the main objective of these experimental approaches has to be harvesting greater amount of protein per hectare without any reduction in grain yields (Jain et al., 1975, 1976).

Keeping in view of the above points, an attempt has been made to evaluate some of the promising strains for yield, yield attributes, nitrogen accumulation and protein content. A detailed study of analysis of variance, correlation among yield, yield attributes, direct and indirect effects of these components on yield, heritability and genetic advance for various characters were undertaken. Studies on the nitrogen accumulation was one of the main objectives of this investigation. The results of the study presented in previous chapter are discussed here.

Analyses of variance in all three maturity groups, revealed highly significant differences for all the thirteen characters and six stages of protein accumulation at grain development, among all the strains and controls of early, medium and late maturity groups separately and pooled together. This indicated that a significant amount of variation existed among the genotypes irrespective of their different maturity periods. Variation was also existed among the genotypes, within the same maturity group and between the maturity groups. Genotypic and phenotypic coefficients of variation values showed differences for all the thirteen characters and six stages of protein accumulation studies undertaken.

5.1 Correlation Studies

The information on association between various traits are very important in a breeding programme. Every aspect of the phenotype of a plant is the result of interaction of a large number of factors. There is ample evidence to suggest that selection directly for yield is not so easy. Selection for one character invariably affects a number of other characters. Thus one realises that it is the whole integrated genotype that is being selected rather than the particular factor that is responsible for the characters we are selecting for. It follows that such correlated response will be of a great importance to the breeder. Favourably correlated responses will considerably accelerate his work, but if it is unfavourable, it might result in erosion of much of the gains obtained by selection. Therefore, it is essential to examine the correlation existing in the population.

In the present investigation, an attempt has been made to determine the nature and extent of association among the yield, its components and protein per cent both in strains and controls of early, medium and late maturity groups in separate and pooled analysis over three years of study, at genotypic and phenotypic levels. In general, the results showed that the genotypic correlations were of higher order in comparison to the phenotypic correlations in the present study, this is in confirmation with the results of Auang et al. (1989) and Iqbal Singh et al. (1990) but Gandhi et al. (1964) observed that in general, genotypic correlation coefficients were of the same magnitude as the phenotypic ones for most of the characters.

The results revealed that the effective tiller number, an important component of yield showed high positive correlation with biomass production at genotypic level in pooled analysis of all three maturity groups. This was in accordance with the findings of Maliksaghir Ahmed et al. (1968); Knot and Talukdar (1971); Jain and Singh (1973); Virk (1973); Adulakh and Virk (1974); Singh (1982); Naik (1988) and Iqbal Singh et al. (1990).

Tiller number showed highly significant positive correlation with grain yield at both genotypic and phenotypic levels in all maturity groups and years of study indicating its strong relationship. Similar observations were made by Malik Saghir Ahmed et al. (1958), Knott and Talukdar (1971), Singh et al. (1972), Jain and Singh (1973), Virk (1973), Adulakh and Singh (1973), Larik (1979), Sinha and Sharma (1980), Kumbhar et al. (1982), Singh (1982), Rychtarik (1985), Vlackh and Smochek

(1986), Naik (1988), Sandhu and Roshan Lal (1989), Olivero-camargo (1989), Deshmukh et al. (1990), Aguilar-Mariseal and Hunt (1991), Thakre and Sontakey (1991) and Palivola and Ral'Ko (1991).

Tiller number showed significant negative relationship with grain weight and grain number per spike in all maturity groups only at genotypic level. Similar observations were made by Abakumenko (1979) in winter wheats regarding the relationship between the effective tillers and grain weight per ear and Larik (1979) with grain number per ear in his studies on wheat mutant.

At phenotypic level, tiller number showed highly significant positive correlations in early maturity group with spike length, grain weight per spike and grain number per spike in support of the earlier report by Ganta (1986) regarding high positive correlations of tiller number with spike length, grain number and grain weight per spike in interspecific hybrid derivatives of wheat. Singh et al. (1973) and Singh (1982) also observed positive correlations of tiller number with grain number per spike. Kolomietes (1986) found positive correlation of effective tillers per unit area with grain weight per spike.

In general, it was observed that tiller number had shown significant negative correlations with plant height, 1000-grain weight, grain number and grain weight per spike both at genotypic and phenotypic levels in late maturity group. These results were in agreement with the results of Hadjichristodoube (1989) with regard to plant height and 1000-grain weight, Larik (1979) with regard to grain per spike and Abakumenko (1979)

with regard to grain weight per spike.

Tiller number was positively correlated in late maturity group with plant height which was in agreement with the findings of Nandpuri et al. (1959).

At both genotypic and phenotypic levels plant height showed significant positive relationship with biomass and 1000-grain weight in early and late maturity groups. Similar but non-significant results were obtained by Stepano and Rudenko (1975). However, in medium maturity group, its positive correlations with days to flower, spike length, grain weight per spike and protein per grain were significant. Similar findings were observed by Stepano and Rudenko (1975) and Singh (1982). Barriga (1974) also found significant positive correlation of plant height with grain number per spike.

Interestingly at both genotypic and phenotypic levels, plant height showed significant positive correlations with protein per grain and significant negative correlation with grain yield. In medium maturity group, which was in confirmation with the results of Singh (1982), Prasanna (1987) and Li (1989). In late maturity group at both levels, plant height had shown significant positive correlations with biomass, 1000-grain weight and protein per grain. Similar but non-significant results were obtained by Stepano and Rudenko (1975).

Biomass had significant positive correlations with plant height at genotypic level in all maturity groups, but none of the characters showed significant correlations with plant height at phenotypic level. On the contrary, it showed significant and negative value for grain yield and protein

yield. Interestingly, this finding is in agreement with the findings in early maturity group in this study. Similar negative correlation between grain yield and plant height was recorded by Singh (1982), Prasanna (1987) and Li (1989). However, this is in contradiction to the findings of Bridgeford and Hayes (1931), Syme (1972), Barriga (1974), Virk et al. (1977), Ali Ahmed Pianchi (1978), Sinha and Sharma (1980), Sota (1983), Hadjichristodoube (1989), Oliveirocamargo (1989) and Sandhu and Roshan Lal (1989), whose findings were positive between grain yield and plant height.

Days to flower showed significant positive correlations with biomass, grain weight per spike and 1000-grain weight at both genotypic and phenotypic levels, in early maturity group and late maturity groups, but correlations with grain yield, spike length and grain number per spike were significant and positive only at genotypic level and with grain number in pooled analysis. These were in consistent with the results of the following authors. Bridgeford and Hayes (1931) reported that grain yield was positively correlated with heading date, Syme (1972) reported high correlations for days to flower with yield. Barriga (1974) reported that days to flower was positively correlated with yield, Sinha and Sharma (1980) and Efremova and Pospelova (1980) also found positive correlation of days to flower with grain yield and Deshmukh (1990) found significant correlation of grain yield with days to flower. Gandhi et al. (1964) and Jain and Singh (1975) had reported significant positive correlation between days to flower and grain number per spike; Jain and Singh got similar result of days to flower with grain weight per spike.

In late maturity group, days to flower had shown high significant negative correlations with biomass, grain yield, 1000-grain weight, protein yield and protein per grain and with 1000-grain weight, protein content and protein per grain. Similar results of significant negative correlation of days to flower with grain yield was found by Jaimini et al. (1974) and Hadjichristodoube (1989) and with 1000-grain weight by Hadjichristodoube (1989).

For biomass, genotypic correlations were observed to be highly significant and positive with grain weight per spike and protein yield in early and medium maturity groups and 1000-grain weight in late maturity group. This was in accordance with the results obtained by Iqbal Singh et al. (1990).

In the late maturity group and pooled analysis, biomass had shown significant positive correlations with grain yield, but non-significant positive association in early and medium maturity groups at both genotypic and phenotypic levels. These findings were in compliance with the findings of Tanno and Goto (1985), Li (1989), Deshmukh et al. (1990) and Saini et al. (1990).

Grain yield showed highly significant positive correlation with harvest index in all the maturity groups at both genotypic and phenotypic levels. This was highly significant and consistent finding in conformity with the findings of Kumbhar et al. (1982), Tanno and Goto (1985), Li (1989) and Deshmukh et al. (1990).

Highly significant positive correlation was found to be between grain yield and spike length in early and medium maturity groups at genotypic level. These results were very much analogous to the findings of following authors viz., Zonjic and Jovanić (1966), Maliksagar Ahmed et al. (1968), Knott and Talukdar (1971), Aulakh and Virk (1973), Jain and Singh (1973), Virk (1973), Singh et al. (1973), Boyadheeva (1974), Jain and Singh (1975), Randhawa (1975), Ali Ahmed Pianchi (1978), Sinha and Sharma (1980) and Kumbhar et al. (1981).

At both genotypic and phenotypic levels, grain yield exhibited strong relationship with grain number per spike in early and medium maturity groups. Similar results were reported by many authors, viz., Gandhi et al. (1964), Zonjic and Jovanić (1966), Malik Saghir Ahmed et al. (1968), Knott and Talukdar (1971), Virk and Verma (1972), Vorober (1972), Singh et al. (1972), Aulakh and Virk (1973), Jain and Singh (1973), Virk (1973), Boyadheeva (1974), Dunder (1974), Mcneal ^{et al.} (1974), Jain et al. (1976), Randhawa (1975), Virk et al. (1977), Ali Ahmed Pianchi (1978), Abakeemenko (1979), Devendra Singh et al. (1979), Larikh (1979), Sinha and Sharma (1980), Singh (1982), Gharzai (1985), Vlakh and Smochek (1986), Kolomietes (1986), Li (1989) and Oliveirochamargo (1989).

In medium maturity group, grain yield showed significant positive correlations with grain weight per spike at both genotypic and phenotypic levels, but in early maturity group these values were significant only at genotypic level. Significant positive correlation of grain yield with grain weight was also reported by the following authors, viz., Weibel

(1956), Sikka and Jain (1958), Vorobev (1972), Dunder (1974), Mcneal (1974), Virk et al. (1977), Kachur (1986), Naik (1988), Barrett ^{et al.} (1989), Deshmukh et al. (1990) and Palilvola and Ral'Ko (1991).

In late maturity group, significant negative correlation of grain yield with grain weight per spike at both genotypic and phenotypic levels was in agreement with the findings of Ali Ahmed Pianchi (1978). In late maturity group, grain yield showed significant positive correlation with protein per cent whereas in medium maturity group, it was positive and non-significant at both genotypic and phenotypic levels. But in early maturity group, protein per cent had shown highly significant negative relationship with grain yield at both genotypic and phenotypic levels. These findings, in early group were in agreement with the findings of Malik Saghir Ahmed et al. (1968), Knott and Talukdar (1971), Aulakh and Virk (1973), Jain and Singh (1973), Virk (1973), Singh (1982), Gharzai (1985), Mahdy (1988), Naik (1988), Li et al. (1989), Lungu et al. (1990) and Li (1990). The results in late maturity group was contradictory to the results found in early group.

The relationship between grain yield and protein per grain was positive and significant in all maturity groups at both levels.

Grain yield showed positive correlation with 1000-grain weight at both genotypic and phenotypic levels in early maturity group, in compliance with the findings of Bridgeford and Hayes (1931), Gandhi et al. (1964), Maliksaghir Ahmed et

al. (1968), Knott and Talukdar (1971), Virk and Verma (1972), Syme (1972), Vorobey (1972), Aulakh and Virk (1973), Jain and Singh (1973), Virk (1973), Singh et al. (1973), Dunder (1974), Jaimini et al. (1974), Jain and Singh (1975), Devendra Singh et al. (1979), Sinha and Sharma (1980), Kolomietes (1986), Naik (1988), Dolotvskii and Nikonov (1989), Hadjichristodoube (1989), Li (1989), Oliv'erocamargo (1989), Sandhu and Roshal Lal (1989) and Deshmukh et al. (1990).

Non-significant negative correlations were found between grain yield and 1000-grain weight in medium and late groups and pooled analysis at both genotypic and phenotypic levels. These were in consistence with the findings of Navtolela et al. (1990).

Harvest index had shown significant positive correlation with grain number and grain weight per spike in early and medium maturity groups at only genotypic level. Similar results were observed by Kumbhar et al. (1982) and Naik (1986). Harvest index showed significant negative correlation with 1000-grain weight, in all maturity groups at genotypic level.

Spike length had shown significant positive correlations with grain number and grain weight per spike at both genotypic and phenotypic levels in maturity groups is in compliance with the findings of Randhava et al. (1975), Abakumenko (1979), Larik (1979), Kumbhar et al. (1981), Jizeng (1984), Naik (1988) and Palilvola and Ral'ko (1991). Spike length showed strong relationship with 1000-grain weight in early maturity group at genotypic level in accordance with the findings of Singh (1982).

Grain number per spike showed significant positive correlation only with grain weight per spike in all three maturity groups at both genotypic and phenotypic levels is in agreement with the findings of Nandpuri et al. (1959), Abokumenko (1979), Ghuzov and Shuman (1981), Kumbhar et al. (1981), Jizeng (1984) and Naik (1988). Grain number also showed significant negative correlation with 1000-grain weight at genotypic level in all maturity groups supported the earlier findings of Barriga (1974).

1000-grain weight per spike had shown non-significant positive correlation with protein per cent in medium maturity group at both genotypic and phenotypic levels. Similar results were reported by the following authors viz., Hirano et al. (1964), Eguchi et al. (1967), Racinski and Racinska (1968), Pepe and Heiner (1975), Siddique and Rajpur (1975), Jain et al. (1976), Singh and Jain (1981) and Naik (1988). 1000-grain weight also showed significant negative correlation with protein per cent in early maturity group at both genotypic and phenotypic levels. These were in accordance with the results reported by Brunori et al. (1982), Mahdy (1989) and Li (1990).

Thousand grain weight showed significant positive correlations with protein per grain in all three maturity groups both at phenotypic and genotypic levels as also reported by Prasanna (1987) in wheat. It showed significant negative correlation with protein yield at genotypic levels.

Protein per cent had shown highly significant positive correlations with protein yield and protein per grain in early

maturity group at both genotypic and phenotypic levels and with protein yield only in medium and late maturity groups at genotypic level.

Table 24 summarises the results of correlation studies of some important yield components with protein per cent and protein per grain in early, medium and late maturity groups and pooled analysis. The analysis shows clearly that in medium and late maturity groups the percentage of protein (score 1) showed significant negative correlations with 1000-grain weight. In sharp contrast to this, all the three maturity groups and pooled analysis show a highly significant positive correlation between protein per grain (score 2) and 1000-grain weight which was also reported earlier by Jain et al. (1975) and Jain et al. (1976) suggest the possibilities of increasing protein content while selecting for grain size in wheat.

One obvious implication of the findings reported here is that it is necessary to score protein per grain when seed size is not taken into consideration. The percentage of protein shows a highly significant negative correlation with seed size; for this reason any improvement secured for this parameter can be expected to be at expense of grain yield. Indeed the failure of many high protein strains to maintain grain yield levels of the control variety can be attributed to this method of scoring protein. However, if selection is first made for increased seed size as suggested here, the percentage of protein in the exceptional genotypes can also be expected to be high.

Table 24: Correlation between protein scores and components of yield in early, medium and late maturity groups and pooled analysis

Characters	Protein scores		Early	Medium	Late	Pooled
	1. Protein per cent	2. Protein per grain				
1. Grain yield/m ²	Vs	Score 1	** -0.6956	0.0899	** 0.9838	0.1658
		2	** -0.7333	-0.7604	-0.2727	* -0.4993
2. Spike length (cm)	Vs	Score 1	** -0.7024	-0.0576	-0.2728	-0.1232
		2	* -0.3741	-0.0806	** -0.9408	-0.0808
3. Grain number/spike	Vs	Score 1	** -0.7938	0.2393	-0.2276	-0.3261
		2	** -0.6304	* -0.3729	** -0.8013	* -0.5836
4. Grain weight/spike	Vs	Score 1	** -0.6149	-0.2595	** -0.8489	-0.2434
		2	** -0.6722	* 0.4252	* -0.5711	-0.0309
5. 1000-grain weight (gm)	Vs	Score 1	0.2755	* -0.3454	** -0.7564	0.2307
		2	** 0.6666	** 0.8466	** 0.9397	** 0.8831
6. Tiller number/m ²	Vs	Score 1	** -0.6860	-0.1546	* 0.3717	* -0.3507
		2	** -0.7795	* -0.4701	** 0.7608	-0.3358
Heritability						
		Score 1	0.8977	0.7187	0.3818	0.8187
		2	0.7152	0.8578	0.6308	0.8545
Genetic Advance						
		Score 1	18.72	10.52	3.85	14.26
		2	20.38	24.53	11.15	28.34

Several authors have reported correlations similar to those described here (Koul, 1973). Thus, Favret et al. (1969) in the case of barley and Harn et al. (1973) in the case of rice observed a positive correlation between the amount of protein in the seed and seed size. They recommended that protein should be scored as protein per grain. Based on these findings in a number of crop plants, a general recommendation has been made that breeders looking for high protein lines should express their results as milligrams protein per seed rather than as nitrogen or protein on a dry weight basis (Hulse, 1975).

Another important implication of the two different scores is that the protein per grain shows much higher heritability and genetic advance (Table 24) than the percentage of protein (Jain et al., 1975; and Jain et al., 1976). The heritability of the protein per grain in wheat seed was found by these authors to be more than 65 per cent while it was less than 25 per cent for this when the selection criteria was on protein per cent.

5.2 Path Analysis

Grain yield is an ultimate product of interaction among its attributes under the influence of environments. These interactions mean indirect effect of these attributes apart from their direct contribution towards yield. Therefore, in addition to determining the interrelationships among the yield components on one hand and between yield and yield components on the other; it is necessary to understand their direct and indirect effects on yield. It is quite likely that contribution of component showing highly significant association with yield may get diluted through the interaction with other components. Further, the information on relative contribution (direct and indirect) of components to yield helps in giving appropriate weightage for the purpose of selection. In view of this, path coefficient analysis had been suggested with emphasis in wheat by Dewey and Lu (1959), Virk and Singh (1973); Jaimini et al. (1974) and Jain et al. (1975).

Path analysis in strains and controls together of early, medium and late maturity groups separately and together in pooled analysis over three years of study revealed that effective tiller number did not contribute directly to yield, but through positive indirect effects via biomass and harvest index in early, late and pooled analysis. These findings are in accordance with the findings of Ganta (1986) and Naik (1988). The direct effect of this character in medium maturity group was positive and this was offset by its indirect negative effects through important yield components such as grain weight per spike and harvest index. Similar positive direct effects

were also reported earlier by Fonseca and Patterson (1968), Virk and Verma (1972), Larik (1979), Singh (1982), Jatasra and Paroda (1985), Vlach and Smochek (1986), Sarkar et al. (1988), Raut et al. (1989), Deshmukh et al. (1990) and Lungu et al. (1990).

The direct effect of plant height on yield was positive in all three maturity groups with the results reported by Jatasra and Paroda (1985), Ganta (1986) and Qian et al. (1989).

Days to flower showed high positive direct effects towards yield in pooled analysis, it was positive in early and late maturity groups but showed relatively low negative value (-0.030) in medium maturity group. Earlier positive direct effect of days to flower towards yield was reported by Ganta (1986) and negative direct effects by Sengupta and Kataria (1971) in soybean, Ali Ahmed Pianchi (1978) and Naik (1988) in wheat. The indirect effects of days to flower seems to be positive in all maturity groups and pooled analysis via tiller number per square metre, plant height and biomass. Its contribution towards biomass in early group is relatively high (0.7586) and via spike length is negative and low. This was in accordance with the findings of Ganta (1986).

The direct effect of biomass on yield was positive and quite high in pooled analysis of three maturity groups together. These effects were positive with low magnitude in early and late groups but negative with low magnitude in medium maturity group. Earlier Deshmukh et al. (1990) and Iqbal et al. (1990) reported highly positive direct effects and Naik (1988) reported very high (-0.917) negative direct effect of biomass on grain yield.

The indirect effects of biomass showed positive and high in magnitude via days to flower (0.4434), harvest index (1.3791) followed by protein per cent (0.9992) and negative and high in magnitude via protein per grain (0.7186), followed by 1000-grain weight (-0.2382) in early maturity group whereas in medium maturity group these effects were positive via tiller number, plant height, harvest index, protein yield, grain number and grain weight per spike, this is in compliance with the findings of Iqbal Singh et al. (1990).

Harvest index had shown very high positive direct effect on yield in early maturity group (0.6647) and late maturity group and negative direct effects of moderately low in magnitude (-0.3277) in medium maturity group. Similar high positive direct effects of harvest index towards grain yield were reported earlier by Kumbhar et al. (1982), Borghi et al. (1985), Naik (1988) and Deshmukh et al. (1990). The indirect effects of harvest index on yield were positive and moderately high in magnitude via biomass (0.5931) and were positive with low magnitude via grain weight per spike, 1000-grain weight and protein per cent in early group, while in medium maturity group, its indirect effects were positive and very high via protein per grain (1.6064) followed by protein yield (0.4616). In late maturity group, its indirect effects were high and positive via protein yield (0.8986) and protein per grain (0.5154) and through grain weight per spike in pooled analysis. Similar indirect effects with low magnitude were reported by Borghi et al. (1985) and with high magnitude by Lungu et al. (1990).

The direct effect of spike length was negative in all three maturity groups as also reported by earlier workers viz., Ali Ahmed Pianchi (1978), Kumbhar et al. (1981), Jizeng (1984) and Naik (1988) also reported high negative direct effects. However, very high positive indirect effects also observed via harvest index (1.2955) and protein per cent (1.4585) in early maturity group, via protein yield (0.5140) in medium group, via protein per grain (0.5136) in late maturity group and via harvest index (0.8416). Gupta et al. (1979), Larik (1979), Kumbhar et al. (1981), Jizeng (1984), Ganta (1986) and Naik (1988) reported high positive indirect effects of spike length via grain number. Ganta (1986) reported its positive indirect effects via tiller number, plant height, grain weight and 1000-grain weight per spike.

Grain number per spike exhibited very high positive direct effect (1.2586) in pooled analysis and low positive value in medium maturity group confirming the results reported by the following authors viz., Fonseca and Patterson (1968), Dadholkar et al. (1970), Phadnis et al. (1970), Badwal et al. (1970), Jaimini et al. (1974), Jain et al. (1975), Devendra Singh et al. (1979), Gupta et al. (1979), Sip and Skorpik (1979), Ghuzor and Malyuzhenets (1981), Kumbhar et al. (1981), Singh (1982), Raseio et al. (1984), Jizeng (1984), Vlakh and Smochek (1986), Ganta (1986), Prasanna (1987), Sarkar et al. (1988), Naik (1988), Qian et al. (1989), Collakee (1989), and Raut et al. (1989).

In early and late maturity groups, the indirect effect of grain number was negative in accordance with the findings of

Ganta (1986) in wheat. The indirect effects of grain number via harvest index (1.2955) and protein content (0.4585) in early maturity group was high and positive, while it was via protein yield (0.9607) and protein per grain (0.7181) in medium maturity group and via protein per grain (0.4373) in late maturity group. Its indirect effect via 1000-grain weight was negative in medium and late groups confirming the results obtained by Ganta (1986).

The direct effect of grain weight per spike showed moderately high and positive in late maturity group and low positive in early maturity group. This was in confirmation with findings of Fonseka and Patterson (1968), Kumbhar *et al.* (1981), Jatasra and Paroda (1985), Dechev (1990), Deshmukh *et al.* (1990) and Lungu *et al.* (1990). The direct effect of grain weight per spike was negative and high (-0.7631) in pooled analysis and negative with low magnitude in medium maturity group, but its indirect effects were positive and high via biomass (1.0907) and harvest index in early maturity group, through 1000-grain weight (1.3622) and protein yield (0.4360) in medium maturity group were in accordance with the findings of Rodrigo and Adams (1972), Ali Ahmed Pianchi (1978), Gupta *et al.* (1979), Ganta (1986) and Naik (1988).

The direct effect of 1000-grain weight was highly positive in medium maturity group (1.7267), and low in late maturity group, and a low negative value in early maturity group. Ganta (1986) reported a low negative direct effect of 1000-grain weight towards grain yield. Its high positive direct effects were reported by the following authors *viz.*, Virk and Verma (1972), Aulakh and Virk (1972), Virk and Singh (1972), Jaimini

et al. (1974), Devendra Singh et al. (1979). Gupta et al. (1979), Sip and Skorpik (1979), Singh (1982), Naik (1988), Sarkar et al. (1988), Collaku (1989), Qian et al. (1989), Raut et al.* (1989) and Deshmukh et al. (1990).

The indirect effects of 1000-grain weight towards yield were positive and high via biomass (0.6366) in early maturity group, infact Virk and Verma (1972) reported positive indirect effects of 1000-grain weight towards yield.

5.3 Studies on Heritability and Genetic Advance

The knowledge of heritability of a character in subject, is of great help for the breeder to proceed in a particular direction basing on their values. Phenotypic performance of individuals are composed of two components i.e. genotypic and environmental. It is the genetic component in which the breeder is interested. The larger the proportion of genotypic component, more the chance of transmitting of the characters to the offspring. Heritability gives an idea of likely success of phenotypic selection.

With the above point in view the broad-sense heritability estimates were worked out. It was observed that genotypic coefficient of variation is generally lower than the phenotypic coefficient of variation for all characters in all maturity groups.

Phenotypic coefficient of variation (PCV) values were highest for grain number per spike, followed by grain weight per spike, tiller number per square metre and plant height in all maturity groups. In addition, high PCV exists for protein per grain and protein yield per square metre in medium and late maturity groups respectively. Similar high PCV values for tiller number and spike length were reported by Pawar et al. (1988).

Genotypic coefficient of variation values were found to be highest for protein per grain in all maturity groups and pooled analysis. Grain number per spike showed highest GCV in late maturity group. Grain weight per spike also showed moderately high GCV in all maturity groups when compared to

rest of the characters. The reason for low PCV and GCV for many characters may be attributed to the stability of strains, since the strains used in this investigation showed stability for all characters in comparison to controls and are quite promising. Most of the strains possess high protein in addition, comparable yields with controls. Infact, similar low genetic variations were reported by Rana et al. (1973) for days to flower, height and kernel weight etc. and Maloo (1984). However Pawar et al. (1988) obtained high GCV for tiller number followed by grain yield and plant height.

The highest heritability estimates were found to be for days to flower, plant height and protein per grain in all three groups of maturity. In addition, 1000-grain weight and grain number per spike showed high heritability estimates. Protein per cent and grain yield were also found to have high heritability. Similar high heritability estimates were observed by Virk et al. (1971). He reported that plant height, days to heading and 1000-grain weight had highest estimates of heritability in broadsense. He concluded that grain number and spikelet number per spike are two components which would be considerable in the selection of parents. Reiter and Leontev (1972) obtained high heritability estimates for grain size, grain number and grain weight per spike than productive tillers and grain weight per spike. The similar results were also reported by the following authors viz., Nurmanov (1972), Kumar et al. (1972), Viswanathan and Kohli (1973), Rana et al. (1973), Hraska (1973), Mariani and Zitelli (1973), Salim et al. (1975), Perwez and Haque (1975), Sharma et al. (1975), Maloo (1984), Gharzai (1985), Sharma et al. (1988), Naik (1988), Pawar (1988), Li et al. (1989), Auang

et al. (1989), Pawar et al. (1989) and Li (1990).

Protein per grain showed highest genetic advance values in early and medium maturity groups and also in pooled analysis. Grain number per spike showed highest value in late maturity group. Along with the above two characters the following traits had high GA in all the maturity groups, viz., plant height, 1000-grain weight, harvest index, grain yield and protein yield. Reiter and Leontev (1972) also reported the greatest genetic advance in response to unilateral 10 per cent selection, that can be expected in number of spikelets per ear, grain number per ear, and grain size. Whereas, selection for productive tillers and grain weight per plant can give the desired effect only with multilateral and highly intensive selection. Viswanathan and Kohli (1973) concluded that grain weight and 1000-grain weight showed high heritability associated with high expected genetic advance and considered most likely to respond to selection. Kumar et al. (1972) also reported that heritable values and estimates of genetic advance were high for 1000-grain weight. Rana et al. (1973) reported highest estimated genetic advance in number of tillers and 1000-grain weight. Perwez and Haque (1975) also reported high heritability and genetic advance values for grains per ear and 1000-grain weight. Maloo (1984) noticed high GA for yield per plant, effective tillers per plant, 1000-kernel weight, plant height and spike length. Sharma et al. (1988) found high heritability and genetic advance for harvest index and Pawar et al. (1989) reported high heritability and genetic advance values for plant height, days to flower and 1000-grain weight than tiller number per plant, grain number per plant and grain yield per plant.

Sharma et al. (1975) reported that heritability values for protein per cent based on variables were upto 9 times as great as the results obtained from regression coefficients, transgressive segregation for protein per cent occurred in particular F_2 plants.

Heritability and genetic advance both are components of direct selection, it is necessary to utilise heritability estimates in conjunction with selection differential which indicate expected genetic gain. As it was found in the present study that heritability and genetic advance values for protein per grain, 1000-grain weight, harvest index, grain yield, grain number and grain weight per spike. Selection criterion based on the above yield components coupled with high protein per grain will enable us in developing varieties with high yields coupled with high protein, since high heritability estimates coupled with high genetic advance for these characters are mainly due to additive effects.

5.4 Nitrogen Accumulation Studies

The analyses of variance for protein per cent, protein per grain and protein yield revealed significant differences among the genotypes of early, medium and late maturity groups.

Analyses of variance for nitrogen accumulation at all six stages of grain development also showed significant differences among the genotypes^{of} all three maturity groups. The studies of Brunori *et al.* (1982) on the kinetics of dry matter and nitrogen accumulation revealed large differences among genotypes as regards the amount per grain and pattern of accumulation of storage compounds during seed development.

The present investigations showed that early maturity group as a whole gave high amount of protein accumulation at Stage I (15 DAF) and stage II (22 DAF) in comparison to medium and late maturity groups showing high efficiency at early grain development period. But at stage III (29 DAF) and stage IV (36 DAF) as expected medium and late maturity groups showed high nitrogen accumulation values than early maturity group. Again at stage V (43 DAF) and stage VI (harvest stage) early maturity group fared better than the other two groups. It is evident from the figure 5. The efficiency of early maturity group with their substantial accumulation of nitrogen at most of the grain development stages at a steady rate from stage II to stage V. Ultimately gave rise to high protein genotypes, whereas the other two groups, though they showed better nitrogen accumulation at stage II and stage III than the early group. They failed to maintain the same rate of accumulation at later stages, with effect final protein values were low, except in

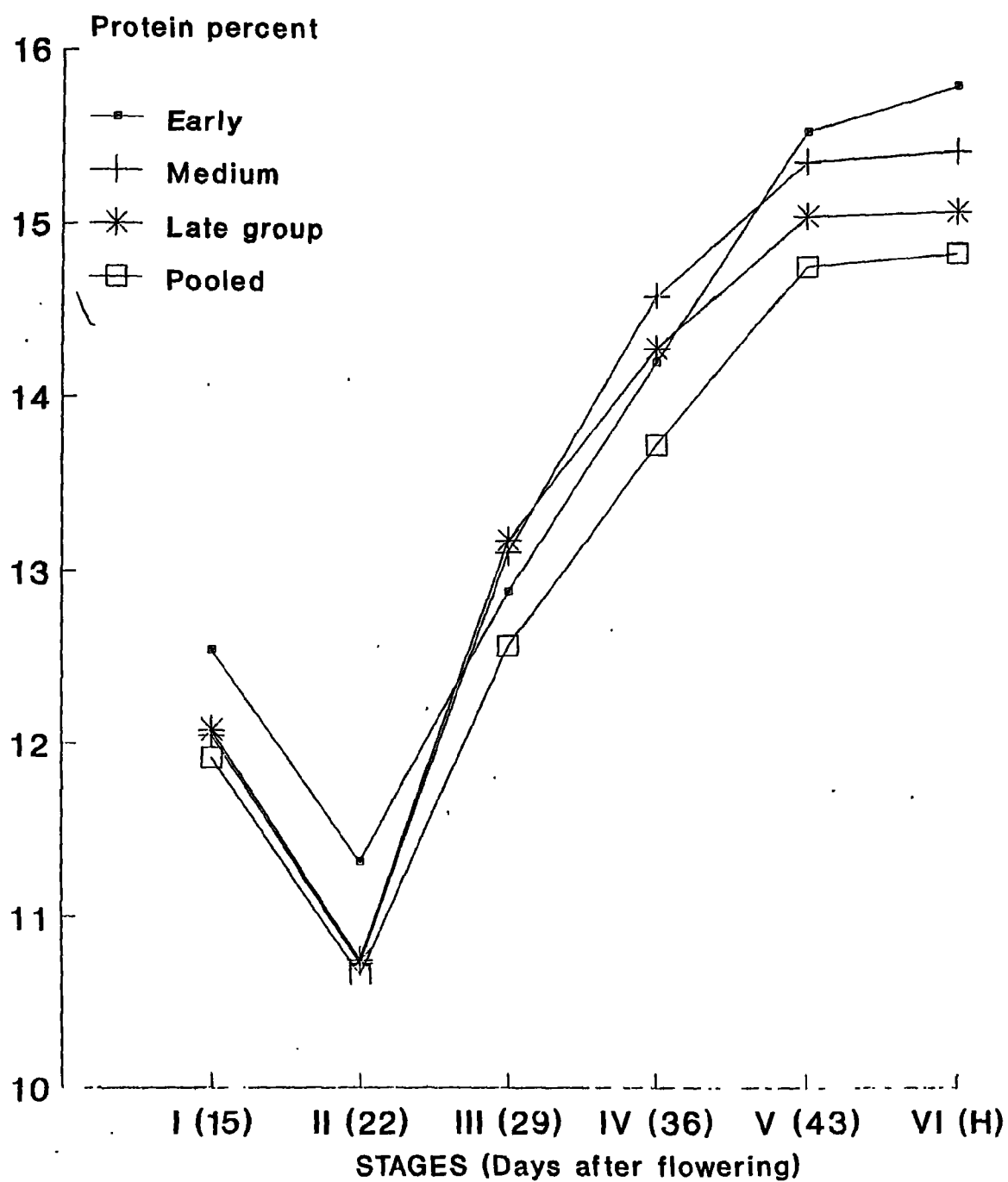


Fig. 5. PROTEIN ACCUMULATION TRENDS IN DIFFERENT MATURITY GROUPS

Pusa 5-3 (17.3) in medium maturity group.

The early maturing strains, P38-15 (16.5), P117-1 (17.8), P117-3 (18.0), P118-2 (17.7) and KLM-26 (17.6) showed high mean protein per cent values, the medium maturity group, strains, P102 (16.3), P108 (15.9), P-577 (15.9), P-766 (16.9) and Pusa 5-3 (17.3) gave high mean protein values and the late maturing strains P-932 (15.8) and P-1035 (15.3) also exhibited high mean protein values.

When all the genotypes of three maturity groups pooled, the trend of nitrogen accumulation throughout the grain development remained quite similar with that of all three groups separately but the amount remained low.

Similar trend of nitrogen accumulation in different genotypes of high protein lines was observed by Brunori et al. (1980) and Brunori et al. (1982). In their study, they had reported that the variability among genotypes of pattern of kinetics of nitrogen accumulation in developing grain of Triticum aestivum has indicated the existence of various genes controlling the process of protein accumulation.

This was evident from the consistency of this trend of protein accumulation over three years of study. Similar trend of protein accumulation was observed in all years of investigation.

The potentiality of nitrogen accumulation of individual strains of early maturity group was plotted against the days after flowering in figure 6, showed that, though the strain P 118-2 (17.7) showed high nitrogen accumulation at upto stage IV except at IIIrd stage where it slowed down than decreased and

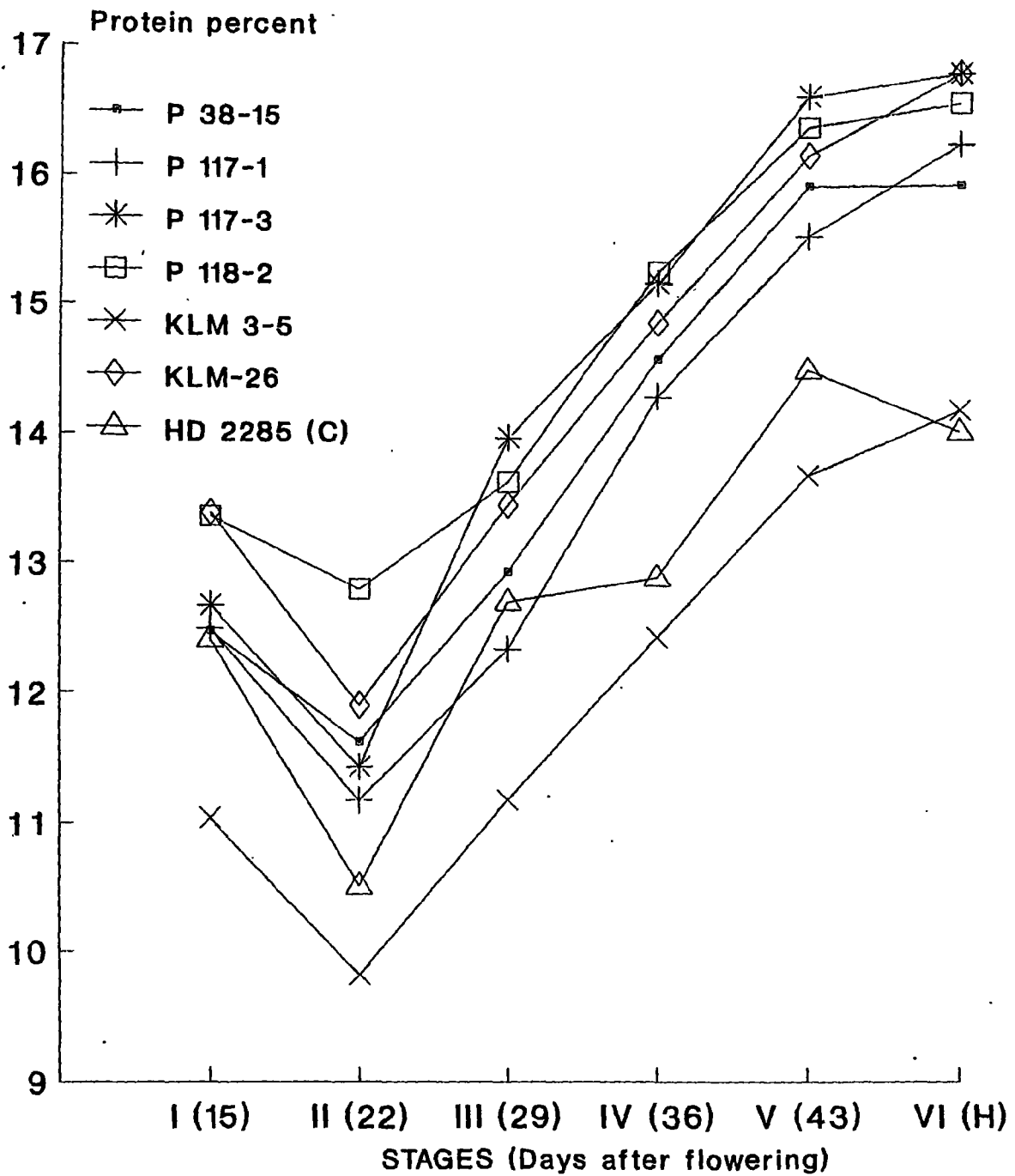


Fig. 6. PROTEIN ACCUMULATION TRENDS IN EARLY MATURITY GROUP

stood 3rd, among the seven genotypes of early maturity group in the order of high efficiency. The most efficient strains among the early maturity group was found to be P117-3 (18.0) even though it was found slightly low at 1st and IIInd stages. It has very high accumulation of nitrogen at stage III and it also maintained in the later stages of growth.

In the early maturing group, all the strains showed high nitrogen accumulation values at all stages except the strain KLM 3-5 in comparison to the Control HD 2285 (14.0). Strain KLM-26 (17.6) is also one of the best in its efficiency. It maintained its rate of accumulation steadily even after stage V where all other strains maintained low levels.

Figure 7 shows the trends of nitrogen accumulation in medium maturity group. It was observed that there is a sudden drop of nitrogen accumulation in all the strains and controls of all three maturity groups. The rate of accumulations decreased drastically at stage II, the possible reason for this low rate is accredited to more accumulation of starch at this stage.

The strain Pusa 5-3 showed tremendous rate of nitrogen accumulation throughout the grain development, at all stages and it gave high protein values among the medium maturity group. Similar performance of Pusa 5-3 was also reported by Brunori et al. (1980), and Singhal and Jain (1981) and Brunori et al. (1982).

All the other strains though showed exceedingly high rate of accumulation between stages II and III then, gradually decreased after fourth stage. The strains P-766 and P-925

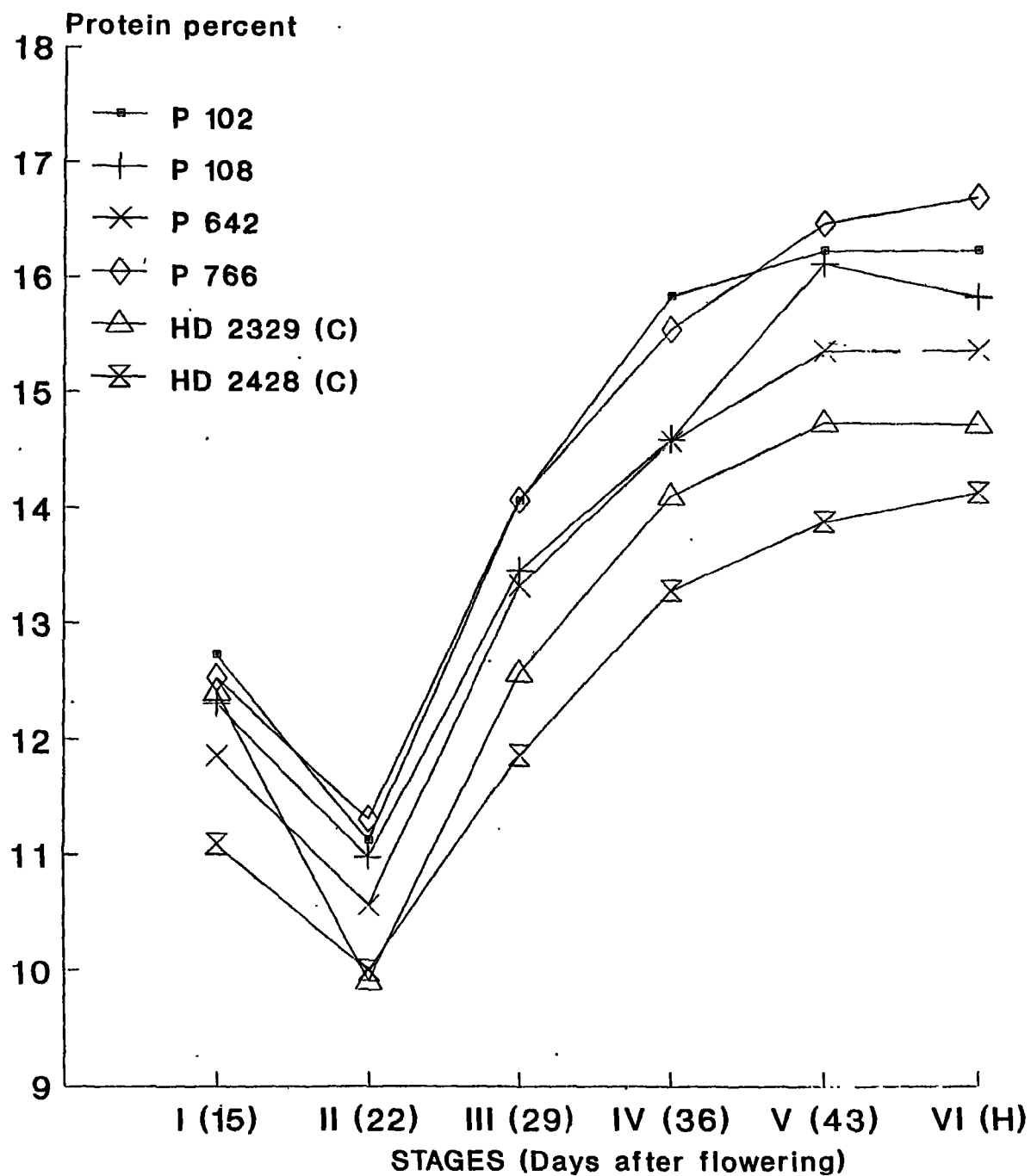


Fig. 7(a). PROTEIN ACCUMULATION TRENDS IN MEDIUM MATURITY GROUP

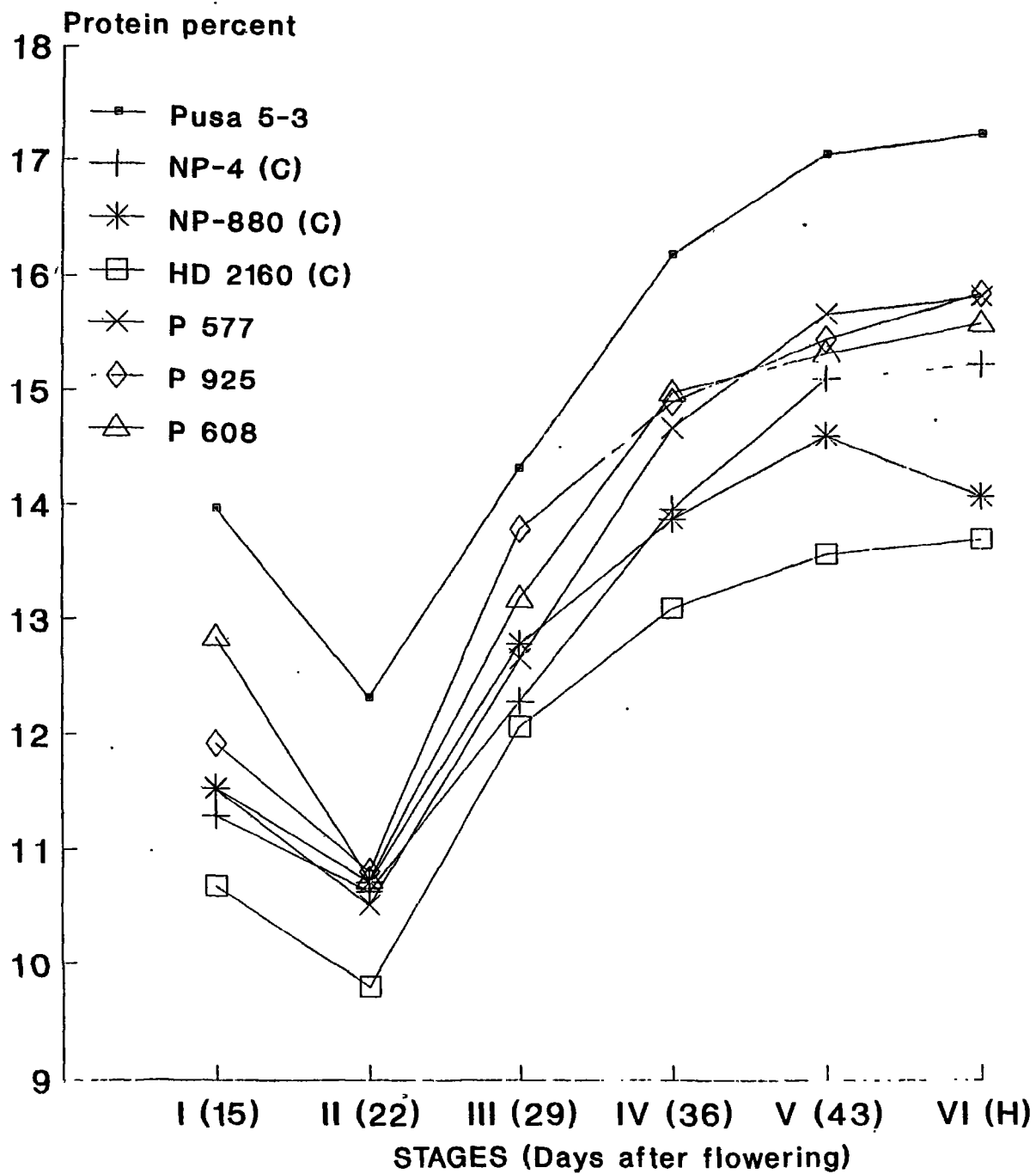


Fig. 7(b). PROTEIN ACCUMULATION TRENDS IN MEDIUM MATURITY GROUP

showed similar trends like the strain Pusa 5-3 but have low protein than Pusa 5-3. Large differences in the pattern of kinetics are evident among strains.

Other strains of medium maturity group are characterised by a rapid rise of rate of nitrogen accumulation but the process of seed growth is relatively short. Pusa 5-3, P-766 and P-925 present slowly increasing rates, that gradually decrease towards the end of seed growth. However, the controls in general possess low rates of nitrogen accumulation but long duration of seed growth. It may be due to the synthesis and deposition of more carbohydrates at later stages which dilutes the protein per cent.

In late maturity group also the trend of kinetics is similar in pattern but the rate of accumulation is varied among genotypes. The cultivar C-306 though gave high accumulation values at initial stages, its rate of accumulation at later stages is very slow and showed lowest protein at harvest among the genotypes of this group. All the strains in general showed rapid *increase* of nitrogen content between stages II and III, but strains P-932 and P-1312 maintained a steady rate upto stage V. The nitrogen accumulation rate of P-1312 even continued at steady rate after 43 DAF, till the harvest.

The seed weight, protein percentage and amount of protein per grain as average values of three years investigation were presented in Table 28. Large differences were evident among the strains and controls for all parameters considered. The high protein strains P117-1 (17.8%), P117-3 (18.0), P118-2

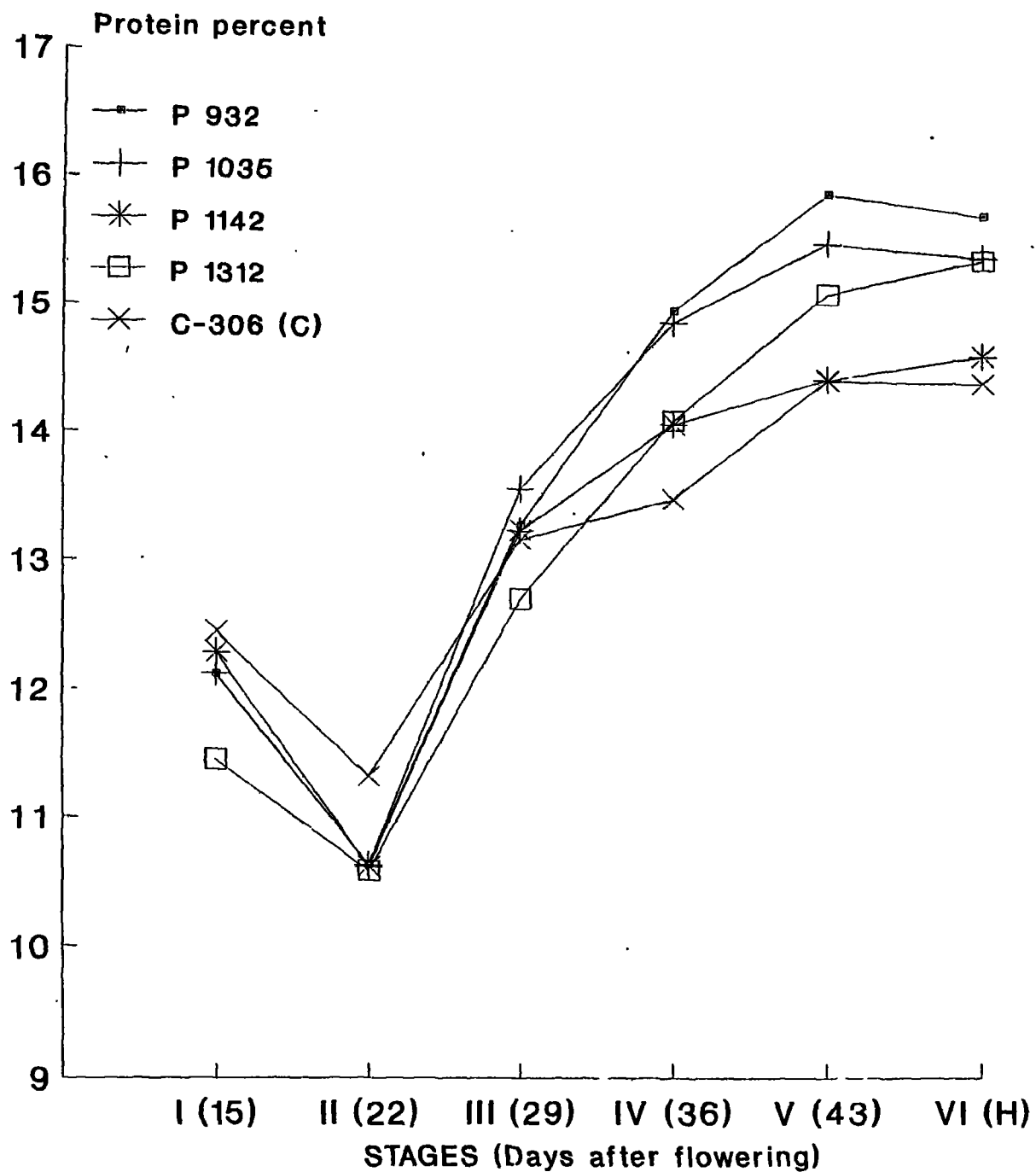


Fig. 8. PROTEIN ACCUMULATION TRENDS IN LATE MATURITY GROUP

Table 28: Seed weight, protein per cent, and protein per grain of wheat seed in different strains and cultivars

Strains/ Cultivars	Seed weight (mg)	Protein per cent	Protein per grain (mg)
Early maturity group			
1. P48-15	39	16.5	6.25
2. P117-1	40	17.8	7.18
3. P117-3	42	18.0	7.44
4. P118-2	43	17.7	7.68
5. KLM 3-5	42	14.6	6.12
6. KLM-26	46	17.6	7.93
7. HD 2285 (Control)	41	14.0	5.82
Medium maturity group			
8. P-102	41	16.3	6.64
9. P-108	35	15.9	5.47
10. P-577	35	15.9	5.47
11. P-608	32	15.6	5.03
12. P-642	36	15.4	5.60
13. P-766	34	16.9	5.80
14. P-925	36	15.8	5.61
15. Pusa 5-3	39	17.3	6.76
16. NP-4 (Control)	33	15.3	5.85
17. NP-850 (Control)	46	14.1	7.97
18. HD-2160 (Control)	37	13.7	5.20
19. HD-2329 (Control)	38	14.8	5.65
20. HD-2428 (Control)	41	14.2	5.79
Late maturity group			
21. P-932	34	15.8	5.34
22. P-1035	32	15.3	5.01
23. P-1142	36	14.6	5.20
24. P-1312	32	15.3	4.86
25. C-306 (Control)	38	14.3	6.03

(17.7%) and KLM-26 (17.6%) among early maturing strains, P-102 (16.3), Pusa 5-3 (17.3) among medium maturing strains and P-932 (15.8) among late maturing strains have larger grain and accumulate higher amounts of nitrogen per grain than other low protein strains KLM 3-5 (14.6), P-1142 (14.6) and P-1312 (15.3). Even the cultivars, NP-880 (14.1) and NP-4 (15.3) are capable of accumulating high amount of nitrogen per grain exceeding that of the strains. P-108 (15.9) and P-608 (15.6), the large seeds of these strains are providing a more capable sink for storage material may represent an advantage over the relatively small grains.

The differences in the pattern of kinetics of nitrogen accumulation indicates that different genes are available that control the process of nitrogen deposition in developing grain.

Finally, if spike fertility is not too reduced seed weight and amount of protein per grain may represent a more efficient sink for the accumulation of storage materials in consideration of the fact that supply of assimilates to the developing grain seems not to be the limiting factor for seed growth.

The experimental findings revealed that grain yield and protein per cent were negatively correlated (Fig. 1) in early maturity group and pooled analysis. It is evident from the performance of the strain KLM 35-5, which gave the mean yield of 44 q/ha and protein content of mere 14.6 per cent. It was found that this correlation was positive in medium and late maturity groups. It is noticeable from the performance of

Table 25: Strains identified for high yields

Strains	Grain yield (q/ha)	Effective tillers/m ²	Grain number/spike	Grain weight/spike (gm)	Harvest index (%)	Spike length (cm)	1000-grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein per grain (mg)
Early maturity group										
1. P38-15	39.0	461.8	42.8	1.69	31.1	9.91	38.5	16.5	63.3	6.25
2. P117-3	38.0	419.7	38.3	1.60	31.4	9.96	41.7	18.0	68.3	7.44
3. KLM 3-5	44.0	475.8	44.8	1.88	33.5	10.56	41.9	14.6	63.6	6.12
4. KLM-26	38.0	401.4	41.2	1.99	27.8	10.59	46.1	17.6	65.7	7.93
Medium maturity group										
5. P-102	46.0	414.9	42.2	1.72	29.9	10.57	40.8	16.3	67.4	6.64
6. P-108	48.0	380.3	49.4	1.71	37.9	11.34	34.9	15.9	75.0	5.47
7. P-577	44.0	438.9	42.4	1.55	31.6	9.78	34.5	15.9	68.9	5.47
8. P-608	43.0	452.9	38.8	1.37	33.0	9.16	32.2	15.6	66.9	5.03
9. P-642	48.0	474.0	40.4	1.54	36.5	9.36	36.4	15.4	73.5	5.60
10. P-766	45.0	456.4	48.5	1.62	31.6	10.36	34.3	16.9	75.2	5.80
11. P-925	46.0	477.4	39.1	1.46	31.4	9.27	35.7	15.8	72.5	5.61
12. Pusa 5-3	39.0	441.4	38.5	1.50	31.8	9.37	37.1	17.3	67.9	6.76
Late maturity group										
13. P-932	46.0	475.2	40.4	1.41	33.0	9.40	33.7	15.8	73.6	5.34
14. P-1312	38.0	380.8	60.5	1.94	28.7	10.13	32.2	15.3	57.6	4.86

Table 26: Strains identified for high protein

Strains	Protein content (%)	Protein yield (g/m^2)	Protein per grain (ng)	Grain yield (q/ha)	Effective tillers/ m^2	Grain number/spike	Grain weight/spike (gm)	Harvest index (%)	Spike length (cm)	1000-grain weight (gm)
Early maturity group										
1. P38-15	16.5	63.3	6.25	39.0	461.8	42.8	1.69	31.1	9.91	38.5
2. P117-1	17.8	66.7	7.18	37.0	385.8	41.3	1.67	30.7	9.59	40.3
3. P117-3	18.0	68.3	7.44	38.0	419.7	38.3	1.60	31.4	9.96	41.7
4. P118-2	17.7	65.8	7.68	37.0	426.0	37.1	1.61	28.3	9.58	43.4
5. KLM-26	17.6	65.7	7.93	38.0	401.4	41.2	1.99	27.8	10.59	46.1
Medium maturity group										
6. P-102	16.3	67.4	6.64	41.0	414.9	42.2	1.72	29.9	10.57	40.8
7. P-108	15.9	75.0	5.47	48.0	380.3	49.4	1.71	37.9	11.34	34.9
8. P-577	15.9	68.9	5.47	44.0	438.9	42.4	1.55	31.6	9.78	34.5
9. P-642	15.4	73.5	5.60	48.0	474.0	40.4	1.54	36.5	9.36	36.4
10. P-766	16.9	75.2	5.80	45.0	456.4	48.5	1.62	31.6	10.36	34.3
11. P-925	15.8	72.5	5.61	46.0	477.4	39.1	1.46	31.4	9.27	35.7
12. Pusa 5-3	17.3	67.5	6.71	39.0	441.4	38.5	1.50	31.8	9.37	37.1
Late maturity group										
13. P-932	15.8	73.6	5.34	46.0	475.2	40.4	1.41	33.0	9.40	33.7

Table 27: Strains identified for both high yields and high protein

Strains	Grain yield (q/ha)	Protein content (%)	Protein yield (g/m ²)	Protein per grain (gm)	Effective tillers/m ²	Grain number/spike	Grain weight/spike (gm)	Harvest index (%)	Spike length (cm)	1000-grain weight (gm)
Early maturity group										
1. P38-15	39.0	16.5	63.3	6.25	461.8	42.8	1.69	31.1	9.91	38.5
2. P117-3	38.0	18.0	68.3	7.44	419.7	38.3	1.60	31.4	9.96	41.7
3. KLM-26	38.0	17.6	65.7	7.93	401.4	41.2	1.99	27.8	10.59	46.1
Medium maturity group										
4. P-102	41.0	16.3	67.4	6.64	414.9	42.2	1.72	29.9	10.57	40.8
5. P-108	48.0	15.9	75.0	5.47	380.3	49.4	1.71	37.9	11.34	34.9
6. P-577	44.0	15.9	68.9	5.47	438.9	42.4	1.55	31.6	9.38	34.5
7. P-608	43.0	15.6	66.9	5.03	452.9	38.9	1.37	33.0	9.16	32.2
8. P-642	48.0	15.4	73.5	5.60	474.0	40.4	1.54	36.5	9.36	36.4
9. P-766	45.0	16.9	75.2	5.80	456.4	48.5	1.62	31.6	10.36	34.3
10. P-925	46.0	15.8	72.5	5.61	477.4	39.1	1.46	31.4	9.27	35.7
11. Pusa 5-3	39.0	17.3	67.9	6.71	441.4	38.5	1.50	31.8	9.37	37.1
Late maturity group										
12. P-932	46.0	15.8	73.6	5.38	475.2	40.4	1.41	33.0	9.40	33.7
13. P-1312	38.0	15.3	57.6	4.86	380.8	60.5	1.94	28.7	10.13	32.2

strains, P-108, P-577, P-766 and P-925 which contributed a mean grain yield of 48, 44, 45 and 46 q/ha and mean protein per cent of 15.9, 15.9, 16.9 and 15.8 per cent, respectively. These above strains of medium maturity group and P-932 (46 q/ha and 15.8%) of late maturity group gave higher yields coupled with higher protein content. The strains with high yield potential and high amount of protein accumulation were identified based on their yield and protein accumulation data of three years of study and are presented in Table 25.

Thus, this investigation brought to light the superiority of strains over controls. The study of mean performance of most of the yield components, protein content and nitrogen accumulation, some of the strains showed better performance over the controls (Appendix-I) in all maturity groups. While dealing with the effective tiller number which mainly contributes to yield, some strains like KLM 3-5 (475.8), P38-15 (461.8) and P118-2 (441) possess higher values than the best control HD-2285 (440.7).

The ultimate yield values of these strains are almost comparable with slightly higher or lower values than HD-2285. The superiority of these strains over the control was shown by lustrous, bold grains, better nitrogen accumulation rates and high protein per cent (2.5 to 3.5% higher than the control). The strains KLM-26, P117-1 and 117-3 possess the higher protein 17.6, 17.8 and 18.0 % respectively with good grains and reasonably good yields. These strains will be quite useful to improve the nutritional quality of the diets.

Among medium maturity group, the strains P-925, P-642 and P-766 showed higher effective tiller number and yield, compared to HD-2329, also showed high protein content. These strains however showed slightly lower yield than HD-2428 but would be useful because of their higher protein levels. Other cultures with good yields and protein content were P-108, P-577 and P-608 comparable with HD-2329 regarding yield. In respect of protein accumulation, Pusa 5-3 showed a very good rate surpassing all other entries in medium group as well as other groups but its main drawback is due to its red grain and low yield. By using this strain in breeding programme several strains like P-38-15, P-117-1, P-117-2, P-117-3, P-118-2 and P-118-3 were evolved with superior grains, high protein, good yields along with earliness.

All the strains from late maturity group possess high effective tillers and yield in comparison to the control C-306. Among them the highest yielder along with high protein was P-932 and its rate of protein accumulation was also found to be at a faster rate except at the IIIrd stage where it was slightly lower.

Basing on the above mentioned facts, several strains above mentioned are very important for using as elite genotypes for improving the protein quality in aestivum wheat but some of them really useful to use directly as cultivars. Further, evaluation of these high protein lines with good grain characters for bread and chapati making properties would go a long way.

6. SUMMARY

In the present investigations, an attempt has been made to evaluate various strains belonging to three maturity groups (early, medium and late) of bread wheat in comparison with high yielding cultivars obtained from the ongoing project of breeding for protein under high yielding background. A major emphasis was given on the kinetics of nitrogen accumulation during grain development in the present investigation. The studies also include analysis of variance, correlations, path coefficient analysis, the estimates of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broadsense (h^2_b), and genetic advance (GA as % of mean). The characters studied were effective tiller number per square metre, plant height, days to flower, biomass production, grain yield per square metre, harvest index, spike length, grain number per spike, grain weight per spike, and 1000-grain weight among yield and its related characters. Among protein related characters, protein per cent, protein yield, protein per grain and nitrogen accumulation studies were undertaken at various stages of grain development.

The salient features of the present investigations are summarised below:

1. Highly significant differences among all the genotypes belonging to early, medium and late maturity groups for all characters and for all stages of nitrogen accumulation were observed.

2. Significant values were obtained for strains for most of the characters such as protein and nitrogen accumulation at all six stages in all maturity groups. For rest of the characters, the values were non-significant but some were at par with the controls.

Strains P38-15 (protein per cent 15.9), P117-1 (16.3), P117-3 (16.9), P118-2 (16.6) and KLM-26 (16.9) in early maturity group, strains P-102 (16.3), P-108 (15.9), P-577 (15.9), P-766 (16.8) and Pusa 5-3 (17.3) in medium maturity group and strains P-932 (15.8) and P-1312 (15.4) showed high nitrogen accumulation.

Strains for more number of tillers were KLM 3-5 (475.8), P38-15 (461.8) in early maturity group, P-925 (477.4), P-642 (474.0) etc. in medium maturity group and P-932 (475.2) and P-1035 (422.3) in late maturity group were identified. In early maturity group, P117-3 (18.0%), P117-1 (17.8), P118-2 (17.7) and KLM-26 (17.6), Pusa 5-3 (17.3), P-766 (16.9) and P-102 (16.3) among medium maturity group and P-932 (15.8) in late maturity group were identified with high protein content. These strains with higher amount of protein per grain also showed high efficiency of nitrogen accumulation. The strain P-108 (48 q/ha), P-642 (48), P-102 (46), P-925 (46) and P-932 (46) etc. gave higher yields.

3. From correlation studies, it was observed that in general genotypic correlations were of higher order in comparison to the phenotypic correlations but similar in significance. Tiller number per square metre possesses high positive correlation with spike length, grain number and grain weight

per spike in early maturity group, with harvest index in medium maturity group and with biomass, grain yield, protein yield and harvest index in late maturity group. Plant height was strongly correlated with biomass and negatively correlated with grain yield. Days to flower was highly correlated with grain yield and other yield determining components.

Grain yield had strong positive association with harvest index, grain number and grain weight per spike in all three maturity groups. Grain yield was negatively correlated with protein per cent in early maturity group and positively correlated in medium and late maturity groups. Most of the strains from medium maturity group gave higher yields coupled with moderately high amount of protein per cent.

Harvest index had strong positive correlations with grain number and grain weight per spike and with protein yield per square metre. Spike length showed highly significant positive correlations with grain number and grain weight per spike along with protein yield in all groups at both genotypic and phenotypic levels. Grain number and grain weight per spike showed strong relationship.

Protein per grain showed highly positive correlation with 1000-grain weight, suggesting that protein scoring based on absolute amount of protein per grain could possibly help us for evolving high protein cultivars coupled with higher yields rather than selections made on protein per cent.

4. Path analysis of the strains and controls together in all three maturity groups showed that maximum direct effect of tiller number on grain yield in medium maturity group, but in

other groups, its positive indirect effects were higher through biomass, spike length, grain number and grain weight per spike.

The direct effect of biomass on grain yield was high (0.6328) in pooled analysis of all groups. Harvest index had highest direct effect (2.5661) on grain yield, in all maturity groups together. Grain number per spike had also shown high direct effect (1.2586) on grain yield in pooled analysis. Its direct effect was negative in early maturity group but indirect effect was positive and high via harvest index (1.2955).

1000-grain weight also showed high direct contribution to the grain yield in medium maturity group (1.7267) and pooled analysis (1.2306).

5. Generally the phenotypic coefficients of variation (PCV) were higher than the genotypic coefficients of variation (GCV) in all maturity groups for all characters studied. High PCV values were observed for grain number and grain weight per spike followed by tiller number and plant height in all three maturity groups.

High GCV values were found for protein per grain in early and late groups but in medium maturity group grain number per spike showed high GCV values.

The highest heritability estimates were found to be for days to flower followed by plant height and protein per grain in all three maturity groups. In addition, 1000-grain weight and grain number per spike showed high heritability estimates.

Protein per grain showed highest GA values in early and late groups and pooled analysis but grain number per spike showed highest genetic advance in medium maturity group.

Heritability and genetic advance both are components of direct selection, it is necessary to utilise heritability estimates in conjunction with selection differential which indicated expected genetic gain. As it was found in the present study that heritability and genetic advance for protein per grain, 1000-grain weight, harvest index, grain yield, grain number and grain weight per spike, selection criterion based on the above yield components coupled with high protein per grain will enable us in developing varieties with high yields and high protein.

6. Nitrogen accumulation studies revealed that genotypes differ themselves in each maturity group and also between maturity groups in accumulating protein, some genotypes accumulate nitrogen at faster rate than others, Pusa 5-3 is one among such genotypes. In general, it was found that early maturity group had high potential for accumulating nitrogen at faster rate than medium and late maturity groups. All the strains belonging to three maturity groups showed high efficiency of nitrogen accumulation in comparison to cultivars in respective groups.

At stage II (22 DAF) all the genotypes manifested low nitrogen values, which may possibly attributed to the higher rate of carbohydrate accumulation at this stage. Nitrogen accumulation in general, was very rapid between stages II and IV.

slowed down between stages IV and V in almost all the genotypes irrespective of their maturity. At stage V (43 DAF) the accumulation seems to be almost maximum and even showed a decreased trend because of other factors. Some exceptional genotypes such as P117-3 (16.9%), KLM-26 (16.9), P118-2 (16.6) and P38-15 (16.0) in early group; Pusa 5-3 (17.3), P-102 (16.3), P-766 (16.8), P108 (15.9) and P-577 (15.9) in medium maturity group and P-932 (15.8) in late maturity groups, demonstrated high potentialities for faster nitrogen accumulation.

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**Appendix I: Treatment means of thirteen characters in strains and controls
of three maturity groups over three years of study**

Strains	Years	C H A R A C T E R S												
		Tiller No./ m ²	Plant height (cm)	Days to flower	Dry wt. of tillers (kg/m ²)	Grain yield (kg/m ²)	Harvest index (%)	Spike length (cm)	Grain number/ spike	Grain weight/ spike (gm)	1000-grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein per grain (mg)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Early maturity group														
1. P38-15	1	521.0	98.3	75.0	1.65	0.41	25.0	10.63	48.4	1.93	39.9	15.8	61.7	6.03
	2	386.0	91.7	74.0	1.10	0.35	31.6	8.47	33.5	1.47	39.6	16.3	56.8	6.46
	3	478.3	80.0	77.0	1.17	0.41	36.7	10.63	46.4	1.67	35.9	17.4	71.4	6.26
	Mean	461.8	90.0	75.3	1.31	0.39	31.1	9.91	42.8	1.69	38.5	16.5	63.3	6.25
2. P117-1	1	390.7	103.3	76.0	1.48	0.38	25.4	9.80	43.7	1.79	41.0	16.7	63.8	6.83
	2	324.0	101.7	75.0	1.13	0.36	31.8	9.50	41.0	1.77	43.1	18.2	64.8	7.83
	3	442.7	83.3	78.0	1.09	0.38	35.0	9.47	39.2	1.44	36.8	18.7	71.4	6.88
	Mean	385.8	96.1	76.3	1.23	0.37	30.7	9.59	41.3	1.67	40.3	17.8	66.7	7.18
3. P117-3	1	481.0	103.3	75.0	1.45	0.38	26.8	10.10	39.3	1.71	43.3	15.7	60.4	6.63
	2	330.7	105.0	71.0	1.09	0.37	34.1	9.80	38.8	1.65	42.4	19.1	70.7	8.11
	3	447.3	88.3	77.0	1.20	0.38	33.2	9.97	36.9	1.45	39.3	19.3	73.9	7.59
	Mean	419.7	98.9	74.3	1.25	0.38	31.4	9.96	38.3	1.60	41.7	18.0	68.3	7.44
4. P118-2	1	514.0	100.0	77.0	1.55	0.40	25.9	9.40	36.8	1.57	42.7	15.9	64.6	6.90
	2	323.0	95.0	74.0	1.25	0.34	27.4	9.80	39.1	1.88	48.1	18.0	62.1	8.68
	3	441.0	88.3	75.0	1.18	0.37	31.5	9.53	35.4	1.38	39.3	19.1	70.8	7.47
	Mean	426.0	94.4	76.7	1.33	0.37	28.3	9.58	37.1	1.61	43.4	17.7	65.8	7.68
5. KLM3-5	1	559.0	101.7	78.3	1.82	0.50	27.7	10.60	43.7	1.71	39.5	14.2	70.9	5.59
	2	491.7	96.7	75.3	1.17	0.46	40.1	10.53	45.3	1.98	43.4	14.3	62.3	6.20
	3	376.7	93.3	78.7	1.18	0.38	32.6	10.53	45.3	1.94	42.8	15.2	57.6	6.56
	Mean	475.8	97.2	77.4	1.39	0.44	33.5	10.56	44.8	1.88	41.9	14.6	63.6	6.12
6. KLM-26	1	501.3	113.3	77.7	1.58	0.45	28.2	10.93	40.2	1.89	45.5	16.8	71.2	7.66
	2	317.3	98.0	76.0	1.17	0.33	28.1	9.73	40.2	1.95	48.4	17.2	56.9	7.87
	3	385.7	96.7	78.7	1.37	0.37	27.0	11.10	41.9	1.86	44.4	18.6	68.9	8.27
	Mean	401.4	102.7	77.4	1.37	0.38	27.8	10.59	41.2	1.99	46.1	17.6	65.7	7.93
7. HD-2285 (Control)	1	507.7	101.7	75.7	1.80	0.49	27.3	10.07	41.5	1.98	40.8	14.2	69.3	5.79
	2	386.0	90.0	74.3	1.07	0.36	33.7	10.20	37.5	1.67	45.9	13.8	57.5	6.35
	3	428.3	93.3	77.3	1.22	0.39	32.8	9.70	46.9	1.76	37.6	14.1	55.1	5.31
	Mean	440.7	95.0	75.8	1.36	0.41	31.2	9.99	44.2	1.80	41.4	14.0	60.6	5.82
Group mean		430.2	96.3	76.2	1.32	0.39	30.6	10.02	41.4	1.74	41.9	16.6	64.9	6.92

Contd....

Appendix-I (Contd...)

Strains	Years	C H A R A C T E R S												
		Tiller No./ m ²	Plant height (cm)	Days to flower	Dry wt. of tillers (kg/m ²)	Grain yield (kg/m ²)	Harvest index (%)	Spike length (cm)	Grain number/ spike	Grain weight/ spike (gm)	1000- grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein per grain (mg)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Medium maturity group														
8. P-102	1	446.7	105.0	87.0	1.67	0.45	27.2	10.43	42.8	1.65	38.7	16.3	73.8	6.31
	2	373.7	105.0	82.0	1.25	0.37	29.9	10.50	41.5	1.83	44.0	16.1	60.2	7.08
	3	424.3	88.3	88.0	1.28	0.41	32.7	10.77	42.6	1.69	39.6	16.5	68.2	6.54
	Mean	414.9	99.4	85.7	1.40	0.41	29.9	10.57	42.2	1.72	40.8	16.3	67.4	6.64
9. P-108	1	379.3	98.3	85.0	1.59	0.54	34.7	11.33	48.0	1.85	38.7	13.8	73.2	5.21
	2	366.0	96.7	84.0	1.18	0.37	31.1	11.23	48.4	1.58	32.7	15.4	56.5	5.03
	3	394.7	93.3	84.0	1.12	0.52	48.0	11.47	51.0	1.71	33.5	18.5	95.4	6.18
	Mean	380.3	96.1	84.3	1.30	0.48	37.9	11.34	49.4	1.71	34.9	15.9	75.0	5.47
10. P-577	1	519.3	101.7	89.0	1.83	0.52	29.1	9.77	43.6	1.49	34.2	14.6	76.6	5.00
	2	356.7	93.3	84.0	1.18	0.37	31.2	9.57	40.7	1.62	33.7	16.5	61.1	5.56
	3	440.7	94.0	89.0	1.26	0.42	34.3	10.00	43.1	1.53	35.5	16.5	68.9	5.83
	Mean	438.9	96.3	87.3	1.42	0.44	31.6	9.78	42.4	1.55	34.5	15.9	68.9	5.47
11. P-608	1	513.3	101.7	87.0	1.17	0.51	29.6	9.30	39.6	1.33	33.5	14.2	72.5	4.73
	2	394.7	100.0	82.0	1.70	0.37	33.7	8.27	38.7	1.35	34.5	16.2	59.8	5.58
	3	450.7	95.0	88.0	1.18	0.41	35.7	8.90	38.3	1.43	28.7	16.6	68.3	4.76
	Mean	452.9	98.9	85.7	1.35	0.43	33.0	9.16	38.8	1.37	32.2	15.6	66.9	5.03
12. P-642	1	587.3	100.0	87.3	1.72	0.53	31.2	9.60	41.8	1.52	36.3	13.4	70.8	4.83
	2	400.6	98.3	89.0	1.25	0.47	37.9	8.97	40.3	1.68	36.1	15.7	74.3	5.64
	3	434.0	100.0	89.0	1.12	0.44	40.4	9.50	39.0	1.44	36.7	17.2	75.3	6.33
	Mean	474.0	99.0	88.4	1.36	0.48	36.5	9.36	40.4	1.54	36.4	15.4	73.5	5.60
13. P-766	1	505.0	100.0	88.3	1.67	0.48	29.1	10.80	46.1	1.44	32.1	16.0	76.5	5.15
	2	361.7	91.7	88.0	1.28	0.42	32.7	10.43	49.3	1.69	35.3	16.8	70.9	5.93
	3	502.7	91.7	88.0	1.36	0.44	33.0	9.83	50.3	1.75	35.6	17.8	78.4	6.33
	Mean	456.4	94.4	88.1	1.44	0.45	31.6	10.36	48.5	1.62	34.3	16.9	75.2	5.80
14. P-925	1	504.0	103.3	89.0	1.78	0.48	27.2	9.77	39.9	1.38	34.7	14.2	68.3	4.93
	2	441.7	100.0	82.0	1.26	0.41	32.7	9.47	38.1	1.63	37.7	16.1	65.7	5.99
	3	486.0	96.7	88.0	1.40	0.49	34.3	8.67	39.3	1.36	34.5	17.1	83.7	5.92
	Mean	477.4	100.0	86.3	1.48	0.46	31.4	9.27	39.1	1.46	35.7	15.8	72.5	5.61
15. Pusa 5-3	1	485.3	106.7	84.0	1.48	0.39	26.3	9.20	43.0	1.55	36.0	16.4	64.1	5.92
	2	350.0	96.7	82.0	1.12	0.34	30.6	9.80	40.6	1.73	42.7	17.1	57.4	7.26
	3	488.0	93.3	84.0	1.20	0.45	38.5	9.10	31.9	1.23	38.6	18.4	82.2	7.10
	Mean	441.1	98.9	83.3	1.27	0.39	31.8	9.37	38.5	1.50	37.1	17.3	67.9	6.76
16. NP-4 (Control)	1	364.3	125.0	87.0	1.32	0.32	24.6	9.27	40.3	1.30	32.3	16.2	51.6	5.21
	2	357.0	110.0	84.0	1.20	0.35	29.6	9.73	39.3	1.36	34.5	14.9	64.4	6.41
	3	426.0	113.3	84.0	1.28	0.40	31.7	9.17	34.4	1.13	32.0	14.8	73.9	5.92
	Mean	382.4	116.1	85.0	1.27	0.36	28.6	9.39	38.0	1.26	33.0	15.3	63.3	5.85

Contd.....

Appendix-I (Contd....)

Strains	Years	C H A R A C T E R S												
		Tiller No./m ²	Plant height (cm)	Days to flower	Dry wt. of tillers (kg/m ²)	Grain yield (kg/m ²)	Harvest index (%)	Spike length (cm)	Grain number/spike	Grain weight /spike (gm)	1000-grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein per grain (mg)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
17. NP-880 (Control)	1	428.3	131.7	87.3	1.70	0.31	18.6	9.33	38.2	1.67	43.8	14.0	48.6	6.88
	2	361.0	125.0	82.0	1.15	0.33	28.6	9.90	40.6	1.90	46.7	14.4	58.8	8.26
	3	411.7	123.3	88.0	1.40	0.37	27.3	9.50	34.9	1.61	46.3	13.9	70.9	8.76
	Mean	400.3	126.7	85.8	1.42	0.34	24.8	9.58	37.9	1.73	45.6	14.1	59.4	7.97
18. HD-2160 (Control)	1	579.3	61.7	83.7	1.43	0.41	29.9	10.23	42.3	1.47	34.8	13.2	55.0	4.60
	2	445.0	64.7	84.0	1.12	0.37	33.8	9.83	41.6	1.64	39.3	14.1	52.7	5.58
	3	474.0	65.0	88.0	1.20	0.46	40.1	10.17	42.0	1.49	35.6	13.9	71.1	5.41
	Mean	499.4	63.8	85.2	1.25	0.47	34.6	10.04	42.0	1.54	36.6	13.7	59.6	5.20
19. HD-2329 (Control)	1	486.3	90.0	87.0	1.72	0.53	31.2	10.33	47.3	1.76	37.5	13.8	73.4	5.16
	2	345.0	91.7	85.0	1.14	0.34	29.9	9.63	37.7	1.57	40.4	15.4	53.9	6.38
	3	439.3	85.0	86.0	1.25	0.52	43.1	10.03	44.2	1.53	34.8	15.2	80.1	5.39
	Mean	423.6	88.9	86.7	1.37	0.46	34.7	9.99	43.1	1.62	37.6	14.8	69.1	5.65
20. HD-2428 (Control)	1	532.3	78.3	84.0	1.68	0.58	34.9	11.27	53.9	2.14	39.7	12.9	74.7	5.11
	2	447.0	76.0	84.0	1.34	0.52	38.8	10.60	33.0	1.68	43.9	14.6	75.3	6.39
	3	491.3	75.0	84.0	1.32	0.49	38.6	11.13	44.9	1.71	38.1	15.1	75.1	5.88
	Mean	490.2	76.4	84.0	1.45	0.53	37.4	11.00	44.0	1.84	40.6	14.2	75.1	5.79
	Group mean	490.9	96.6	85.8	1.37	0.43	32.6	9.94	41.9	1.58	37.0	15.5	68.8	5.91
Late maturity group														
21. P-932	1	480.7	108.3	91.7	1.77	0.42	25.5	9.27	41.6	1.41	34.0	14.6	61.4	4.96
	2	503.0	100.0	92.0	1.21	0.49	40.5	9.70	39.3	1.58	36.8	16.3	79.7	5.98
	3	442.0	96.7	91.0	1.48	0.48	33.0	9.23	40.3	1.23	30.4	16.7	79.5	5.08
	Mean	475.2	101.7	91.6	1.48	0.46	33.0	9.40	40.4	1.41	33.7	15.8	73.6	5.34
22. P-1035	1	454.2	110.0	93.0	1.46	0.33	23.4	10.47	58.0	1.90	32.7	14.6	48.3	4.78
	2	370.0	95.0	93.3	1.12	0.35	31.6	10.07	59.2	1.96	33.1	15.4	54.5	5.08
	3	442.7	100.0	95.0	1.14	0.41	36.7	10.43	56.9	1.80	31.5	15.8	66.5	5.18
	Mean	422.3	101.7	93.8	1.24	0.36	30.6	10.32	58.0	1.89	32.4	15.3	56.4	5.01
23. P-1142	1	438.3	105.0	92.3	1.65	0.37	22.7	10.27	57.5	2.21	36.2	14.5	53.5	5.26
	2	363.3	93.3	93.0	1.18	0.34	29.1	10.33	55.9	2.01	36.0	13.4	46.0	4.83
	3	370.7	96.7	95.0	1.28	0.36	28.4	10.07	55.4	1.92	34.4	16.0	57.0	5.50
	Mean	390.8	98.3	93.4	1.37	0.36	26.7	10.22	56.3	2.05	35.6	14.6	52.2	5.20
24. P-1312	1	394.0	103.3	93.0	1.63	0.39	23.9	10.43	61.3	1.88	31.2	15.2	59.0	4.72
	2	363.7	98.3	94.0	1.20	0.36	30.9	10.23	59.0	1.92	32.5	14.7	50.7	4.55
	3	384.7	100.3	95.0	1.28	0.39	31.2	9.73	61.3	2.01	32.8	16.1	63.0	5.30
	Mean	380.8	100.7	94.0	1.37	0.38	28.7	10.13	60.5	1.94	32.2	15.3	57.6	4.86

Contd....

Appendix-I (Contd...)

Trains	Years	CHARACTERS												
		Tiller No./ m ²	Plant height (cm)	Days to flower	Dry wt. of tillers (kg/m ²)	Grain yield (kg/m ²)	Harvest index (%)	Spike length (cm)	Grain number/ spike	Grain weight /spike (gm)	1000- grain weight (gm)	Protein content (%)	Protein yield (g/m ²)	Protein per grain (mg)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
5. C-306 (Control)	1	565.0	123.3	97.7	1.92	0.35	19.4	9.50	50.0	1.73	34.3	14.4	55.1	5.11
	2	389.3	123.3	92.3	1.23	0.35	29.5	9.90	43.6	1.85	42.5	14.3	55.4	6.66
	3	328.7	126.7	92.0	1.25	0.32	26.0	9.57	46.7	1.75	37.6	14.1	53.8	6.31
	Mean	427.4	124.4	92.0	1.46	0.34	25.0	9.66	46.8	1.78	38.1	14.3	54.8	6.03
	Group mean	419.3	105.4	93.0	1.39	0.38	28.8	9.95	52.4	1.81	34.4	15.1	73.6	5.29
	I year mean	485.5	103.0	84.9	1.65	0.44	27.0	10.08	45.5	1.69	37.3	14.9	64.7	5.57
	II Year mean	381.9	97.5	83.1	1.18	0.38	32.4	9.89	42.5	1.72	39.7	15.8	61.1	6.39
	III Year mean	433.3	94.3	85.7	1.25	0.42	34.5	9.92	43.5	1.59	36.5	16.5	71.2	6.24
Grand mean		433.6	98.3	84.6	1.36	0.41	31.3	9.96	43.8	1.67	37.9	15.7	65.7	6.07

